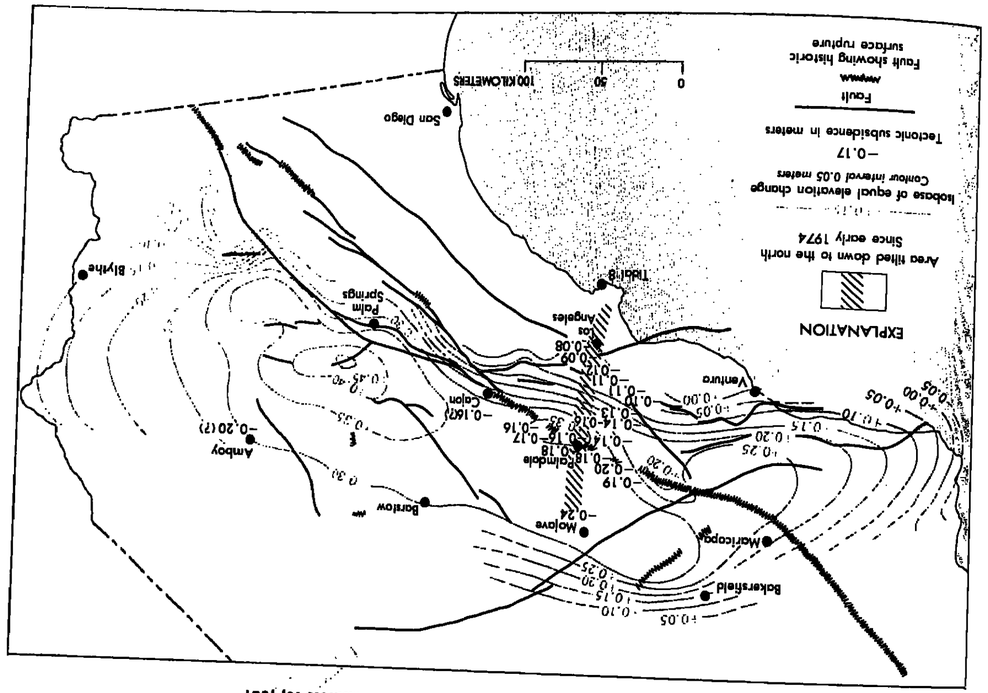

TRANSACTIONS, AMERICAN GEOPHYSICAL UNION
VOLUME 62 NUMBER 10 MARCH 10, 1981

Social Sciences

3310 Economics
ECONOMICS OF RAINFED CROPPING SYSTEMS: NORTHEAST THAILAND
D. M. Johnson, III (The Ford Foundation, P. O. Box 11-1096, Siam Post Office, Bangkok 11, Thailand) and C. Charoenwattana

Using a computer model to simulate effective rainfall it is shown that a flexible rainfed cropping based on a legume planted before rice has a greater expected return than present subsistence systems. Combining a legume crop intercropped with cassava or kenaf further increases the expected returns. Stable markets for legumes is expected to be more significant than extension acceptance.

Water Resour. Res., Paper 1W0316

3370 Politics
PROJECT GRANT ALLOCATION PROCESS APPLIED IN SEWERAGE PLANNING
Yoshiki Nagahara (Nihon Suido Consultants Co., Ltd., Dai-3 Matsuda Bldg., 2-6, 2-chome, Otowa, Shinjuku-ku, Tokyo, Japan) Kiyoko Nagahara

A model is given for sewerage planning which is carried over a region controlled by a number of local governments, whereas the total grant allocated to this region is promulgated by the central government. A regional linear programming model is first set up, and using a method of decomposition it is shown that this method lends itself to a decision making process, in which information is exchanged between the two levels, that is a decentralized decision making process can be applied to centralization problems. The project grant allocation, sewerage planning, two-level system, water quality, decomposition principle, coordination.

Water Resour. Res., Paper 1W0057

Solar Physics, Astrophysics, and Astronomy

7743 Radio astronomy
VARIATIONS IN THE MEASUREMENT OF THE ROTATION PERIOD OF SATURN'S MAGNETIC FIELD
W. D. Desch (NASA/Goddard Space Flight Center, Planetary Magnetospheres Branch, Laboratory for Extraterrestrial Physics, Greenbelt, MD, 20771) and M. L. Kaiser

We determine Saturn's radio rotation period using measurements made by the Planetary Radio Astronomy experiment onboard the Voyager spacecraft. The interval period doubled, 10 hr 39 min ± 7 sec, is within the 10 hr to 11 hr range of optical periods derived from a number of atmospheric spot and Doppler spectroscopy observations. The radio rotation period is presumably that of the planet's magnetic field. We propose a provisional Saturn longitude coordinate system, and we provide equations to compute a longitude ephemeris and to transform between the proposed system and the 1958 or 1-mid system used for the Pioneer 11/Saturn encounter. In addition, we evaluate the degree of longitude smearing which could result over the long term from the merging of data sets organized in this system. Finally, no evidence of control of the radio emission by any of Saturn's satellites is found. (Saturn's rotation period).

Geophys. Res. Lett., Paper 8NL1845

7799 General or miscellaneous
A FIREBALL IN JUPITER'S ATMOSPHERE
A. F. Cook (Harvard-Smithsonian Center for Astrophysics, 60 Garden St., Cambridge, Massachusetts 02138) and T. C. Duxbury

One fireball was photographed during two encounters with Jupiter. Its total luminosity was 1.2×10^6 s mag sec (at standard range 100 km). If we employ the luminous efficiency proposed by Cook et al. (1980) for slip flow of a meteoroid in his own vapors we obtain an estimated mass of 11 kg. A rough absolute magnitude 223^p during two exposures, we estimate a number density near Jupiter of 7×10^{-28} cm^{-3} for masses of meteoroids of 3 kg and greater. This value is about a factor of six smaller than a rough upper limit reached from an extrapolation from terrestrial observations of meteors and comets.

J. Geophys. Res., Green. Paper SOC1832

Tectonophysics

8110 Convection currents
A POSSIBLE MANTLE INSTABILITY DUE TO SUPERPLASTIC DEFORMATION ASSOCIATED WITH PHASE TRANSITIONS
E. M. Parmentier, Department of Geological Sciences, Brown University, Providence, RI 02912

Laboratory deformation studies of metals and some oxides indicate that these solids are easily deformed while undergoing a phase transformation. This superplastic effect, if it occurs for mantle silicates, may result in an instability of mantle flow. The instability is illustrated by considering a sheared layer of viscous fluid containing a phase transition. With a simple idealization of the phase transition weakening effect, an oscillatory fluid motion which cycles material through the phase transition is shown to reduce the rate of viscous dissipation associated with shearing the mantle flow include the partial decoupling of mantle layers at phase transitions and short wavelength free air gravity anomalies due to induced normal stress variations at the base of the lithosphere.

Geophys. Res. Lett., Paper 1L0124

8150 Plate tectonics
OBSERVATIONS OF FLEXURE AND THE RHEOLOGY OF THE OCEANIC LITHOSPHERE
J. H. Bodine (Lamont-Doherty Geological Observatory of Columbia University, Palisades, N.Y.) and M. S. Steckler and A. B. Watts

Observations of flexure indicate the effective flexural rigidity of oceanic lithosphere is a function of the age of the lithosphere, and hence temperature, at the time of loading. We have used a yield stress envelope model constrained by data from experimental rock mechanics to determine how the flexural parameters and rheologic properties of oceanic lithosphere are related. The results of our model for seamounts and oceanic island loads in the interior of plates suggest that following loading, rapid stress relaxation occurs as the plate "thins" from its short-term to its long-term ($\sim 10^5$ years) mechanical thickness. The mechanical thickness, which determines the effective flexural rigidity of the plate, is strongly dependent on temperature and weakly dependent on load size and duration (1-10 m.y.). The results of our model for convergent plate boundaries suggest that changes in the shape of the Outer Rise along an individual trench system may be due to variations in the horizontal load acting across the boundary (flexure). The model predicts a narrow zone of high strain accumulation seaward of a trench which is in agreement with variations in crustal velocities and seismicity patterns observed along some trench systems. (Flexure, rheology, stress relaxation, isostasy, subsidence).

J. Geophys. Res., Red, Paper 1B0025

Volcanology

8699 Volcanology topics
VOLCANICS AND STRUCTURE OF THE FAMOUS-AMBRONAUT RIFT: EVIDENCE FOR CYCLIC EVOLUTION: ANNE I. K. Crane (Woods Hole Oceanographic Institution, Woods Hole, MA 02543, now at Lamont-Doherty Geological Observatory, Palisades, NY 10964) and R.D. Ballard

A near-bottom photographic survey on the Mid-Atlantic Ridge from the FAMOUS region south to Transform B reveals structural and volcanologic evidence for an alternating widening and narrowing rift valley. Extension wedges appear to be propagating south from Transform A and north from Transform B. These wedges at Mt. Harr where the rift valley is narrowest and shoalest (Narrowgate), giving the valley a symmetrical hourglass shape. Three major volcanic en echelon lineaments trend N10°E, 10° oblique to the strike of the inner rift walls. Faulting and fissuring are antisymmetrical across the rift valley in contrast to the major extension. This contrasting antisymmetry of inner surficial distribution of struct across the rift of varying strength, whereas the large-scale wedge phenomenon determines the periodicity of transition from a narrow valley to a wide valley. Using vector analysis, the extension wedges are propagating at about 9 cm/yr towards each other. At this rate, a narrow rift valley will be fully transformed into a wide rift in 0.64 m.y.

J. Geophys. Res., Red, Paper 1B0114

8699 Volcanology topics
THERMAL PROPERTY MEASUREMENTS IN A FRESH PUMICE FLOW AT MT. ST. HELENS
N. C. Sorden (Sandia National Laboratories, Division 4743, Albuquerque, NM 87185)

A thermal penetrator that was air dropped into a freshly emplaced pumice flow at Mt. St. Helens yielded information on the in-situ thermal properties of the pumice. The in-situ conductivity-density-specific heat product at a depth of 0.5 m was found to be 7.34×10^{-3} cal^2/cm^4-°C-s at an average pumice temperature of 200°C. Using this data, values for the average in-situ thermal conductivity (2.3×10^{-3} cal/cm-°C) and thermal diffusivity (1.2×10^{-3} cm^2/s) were estimated. These thermal properties are of use in studies of pumice cooling and in the interpretation of infrared remote sensing data.

Geophys. Res. Lett., Paper 1L0127

Editorial

Why Should I Invest in AGU?

This question is addressed to three age groups within the AGU membership—the young, the middle age, and the 'you're looking fine' group. For you, the reader, we give the responses.

As a junior member of the society I note the excitement of the meetings, the intensity of the discussion—especially in the lobbies, over coffee or with beer; and the high quality of papers in the journals. I know of no better place to exchange ideas with others from all parts of the country or even the world. AGU is a scientific forum with geophysical dimensions. I applied for membership because I wanted to be a part of it, and I am looking forward to a full career in geophysics. I can see the pleasure and satisfaction my seniors are deriving from their careers. The AGU seems to be a common bond for them. Why should I invest in AGU? I am planning for the future, and I expect AGU to be an important part of my life.

I have been a member of AGU for a little over 20 years. My enthusiasm for geophysics came from IGY, Vanguard, Minitrack, Mohole, World Wide Seismic Nets, and such. It seems a long time ago. With the scope of scientific knowledge doubling every 10 years, I would have been left far behind, essentially lost, without AGU to help keep me informed through its journals and meetings—a key factor in my continuing education. I have been an educator, but now I am on the 'receiving' end in scholastic matters. As a manager, my primary concerns seem to be people and services, but the geophysical sciences and their applications to the solution of societal needs are the fundamentals we strive to convert to profit. I look forward to another 10 years with another 'doubling.' So why should I invest in AGU? It is the same as 'plowing profits back into the firm.' The dividends I return to AGU help to ensure that in 1991 the AGU will continue to be 'educating' me. The financial record of AGU over the past 60 years is excellent. My support at this time is one of the best investments I can make.

Membership and participation in the affairs of AGU have been a major part of my life in the profession I've followed for the last 40-plus years. I've found pleasure in my work and have enjoyed the association with my colleagues, and even though in these later years I cannot attend as many of the meetings, I look forward to receiving the abstracts and reports of the advances in geophysics. I have been blessed to have lived in the 20th century. There have been ups and downs, but being in geophysics, the ups prevailed. Now I look at money market returns, conservative investments, and discounts for senior citizens. So why should I invest in AGU? To ensure that this generation and the ones to follow will have the same, or even greater, benefits. Contributing to an endowment sufficient to ensure an adequate reserve and supporting worthy programs in geophysics exemplifies unselfish cooperation, and to me, with my limited needs, these represent very sound 'investments.'

Charles A. Whitten
Earl G. Droessler
Co-Chairmen
GIFT Steering Committee

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The Weekly Newspaper of Geophysics
Editor A. F. Spilhaus, Jr.

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Cover. Tectonic setting of the Celebes Basin. All presently active plate boundaries are depicted by continuous lines and former plate boundaries by broken lines. Convergent plate boundaries are denoted by the sawtooth lines with sawteeth on the overriding plate. Spreading centers are marked by solid lines with outward-pointing bold arrows. Strike-slip zones are solid lines, with sense of motion defined by the arrows. The diagonally hatched region illustrates the broad region of current plate interactions. It is characterized by compressional tectonics and zones of shear (generally, left lateral). [Illustration taken from paper by J. Weissel, Evidence for Eocene oceanic crust, in *The Tectonic and Geologic Evolution of Southeast Asian Seas and Islands, Geophysical Monograph 23*, edited by D. E. Hayes, published by American Geophysical Union; see page 112.]

Radioisotope Detection and Dating with Accelerators

A. E. Litherland and J. C. Rucklidge
University of Toronto

Recent developments in mass spectrometry have made possible the direct detection of many naturally occurring long-lived radioisotopes. Radioactive atoms are present at such low concentrations that the sensitivity of the mass spectrometry has to be increased to detect parts per quadrillion (10^{15}) in a sample. This sensitivity has been achieved, and some of the results taken at Rochester by the Rochester (University), Toronto (University), General Ionex (Corporation) collaboration are listed in the table. All the radioactive isotopes listed in the table are of importance in geochronology, and for ^{14}C and ^{36}Cl, sensitivities better than parts per quadrillion (10^{15}) have already been reached. Early work on the stable isotopes of platinum has already reached below parts per billion (10^9).

Mass Spectrometry of Rare Isotopes

	Half-Life, million years	Sensitivity Reached
^{10}Be	1.6	7 ppq
^{14}C	0.00057	0.3 ppq
^{26}Al	0.72	10 ppq
^{36}Cl	0.31	0.2 ppq
^{129}I	16.0	300 ppq
Pt	stable	10 ppt

ppb, parts per billion (10^9); ppt, parts per trillion (10^{12}); ppq, parts per quadrillion (10^{15}).

These advances in mass spectrometry techniques, which represent a new frontier in geochronology and in secondary ion mass spectrometry (SIMS) of minerals, are based on the following principles:

1. The rare radioactive atoms in a sample are counted instead of the particles emitted during their radioactive decay.
2. High mass spectrometer resolution, and hence low mass spectrometer efficiency, is avoided by destroying completely the interfering molecules.
3. Interfering atoms with nearly the same mass (isobars) are eliminated if possible, and if necessary, by a number of techniques.

The advantages of ion counting can be illustrated by the detection of ^{14}C in the biosphere. The cosmic-ray-produced ^{14}C in contemporary biological carbon emits 15 beta rays per minute per gram. This beta ray counting rate, together with the known 5730-year half life of ^{14}C, requires the presence of 6.5×10^{10} ^{14}C atoms per gram of carbon or about 1 part of ^{14}C per trillion (10^{12}) of ^{12}C. Clearly counting atoms is a potentially more sensitive technique than waiting patiently for the beta rays from radioactive decay.

The counting of the ^{14}C atoms or ions by mass spectrometry is made difficult by the presence of large numbers of molecules such as $^{12}CH_2$ and ^{13}CH, which have nearly the same mass as ^{14}C. These molecules are readily destroyed after acceleration to a suitable velocity or energy. The high-velocity molecules are readily dissociated in collisions with gas atoms such as argon. For the dissociation to be complete it is necessary to use a velocity such that at least three electrons are removed from the molecule. This requires, in the case of carbon, an ion energy of 2.6 MeV, which is about 100 times as great as used in the conventional mass spectrometry. At 2.6 MeV, 50% of the atoms become C^{3+}, and no molecules are left to interfere with the $^{14}C^{3+}$ ions.

The interfering $^{14}N^{+3}$ ions are most easily eliminated by using negative ions at the outset, as the N^- ion is unstable, whereas the C^- ion is quite stable. This simple solution avoids the necessity of very high resolution mass spectrometry or the use of more complicated and difficult schemes for distinguishing between the ^{14}N and ^{14}C atoms. In addition the use of negative ions simplifies the destruction of the molecules because a tandem accelerator can be used. In this type of accelerator the negative ions are attracted toward a positive electrode in which the electrons are removed to make positive ions, and the molecules are dissociated. The positive ions are then accelerated to ground potential. In this way the negative and positive ion mass spectrometers and ion sources can all be conveniently near ground potential.

The final atom counting is usually done with detectors that measure the ion energy, velocity, and rate of energy loss. The rate of energy loss measurement can also discriminate between light ions, such as ^{14}N and ^{14}C, and even ^{36}Cl and ^{36}S, and so add confidence in the identification of the atoms of interest.

The apparatus used for ultrasensitive mass spectrometry at Rochester University is shown schematically in Figure 1. It is normally used as an accelerator system for nuclear physics studies, and it has been modified for mass spectrometric measurements. The negative ions are generated by cesium sputtering from solid samples, and in the case of ^{14}C detection, mass 14 ions are selected by a mass spectrometer prior to injection into the 27-m-long molecular disintegrator. Ion current can be measured by a removable Faraday cup (FC 1) prior to injection. The negative ions are accelerated to 8 MeV in this case, and are converted to C^{+4} ions, which is just as effective in eliminating molecules as the conversion to C^{+3} ions at lower energies. A second mass spectrometric system for the positive ions is used to eliminate the molecular fragments. This is followed by devices to measure the time of flight of the ions, their energy, their rate of energy loss, if possible, and finally to count the ions.

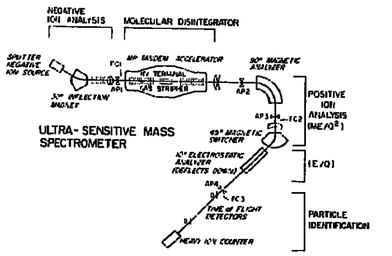

Fig. 1. The ion beam transport system of the tandem-accelerator-based ultrasensitive mass spectrometer at the University of Rochester is shown schematically. Ion-beam-defining apertures are designated AP, and Faraday cups for ion current measurements are designated FC.

The pulse spectrum from the ion detector is shown in Figure 2 for two samples of carbon. The top spectrum is from a carbon sample provided by the U.S. Geological Survey from wood buried by an eruption of Mt. Shasta, in California, 4600 years ago, and the bottom spectrum is from graphite prepared from very old carbon. The change in the ^{14}C counts is quite evident. The ^{14}C concentration in the graphite sample is less than about 0.3 ppq. The ^{13}C and ^{12}C ion counts are due to molecular fragments, and they can be eliminated completely if an electrostatic analyzer is used also.

The procedure for evaluating isotope ratios is to measure the ion currents of the $^{12}C^{+4}$ and $^{13}C^{+4}$ in FC 2 or $^{12}C^{+4}$ ion current in FC 1 and the $^{14}C^{+4}$ counting rate in the heavy ion detector. One microampere of singly charged ions is equivalent to 6.25×10^{12} ions per second.

The results from the measurements on some carbon samples of known age are shown in Figure 3. These samples were provided by M. Rubin of the U.S. Geological Survey, and the logarithm of the measured counts of ^{14}C per minute per microampere of $^{12}C^-$ current is plotted against the known age of the samples. As expected, the measurements lie on a straight line because of the exponential radioactive decay law. It is worth noting that the ^{14}C concentration at 40,000 years is about 1 part ^{14}C per quadrillion of ^{12}C or 1 part in 10^{15}.

The carbon samples used to obtain the data shown in Figure 3 weighed about a milligram, and so for the 40,000-year-old sample one would expect one beta ray to be emitted per month. This dramatically illustrates the increase in sensitivity resulting from atom counting.

The maximum sensitivities achieved at Rochester for other long-lived radioactivities are shown in the table. Elsewhere, work on several of these radioisotopes has been extensive and will now be summarized.

1. ^{10}Be has been extensively studied by G. Raisbeck et al. (Laboratoire René Bernas, Orsay, France) in samples of geophysical interest, such as ice from Antarctica, ocean water, rainwater, deep ocean sediment, and in manganese modules, by K. K. Turekian et al. (Yale University). The work by Raisbeck et al. was carried out by using positive ions and a cyclotron, with discrimination between ^{10}Be and ^{10}B being achieved by range separation. ^{10}Be is particularly easy to observe, and it is expected that negative ions and small inexpensive tandem accelerators about 2 m long will be quite sufficient for detection and measurement.
2. Extensive work on ^{14}C is taking place at many laboratories, and three specialized machines, to be described later,

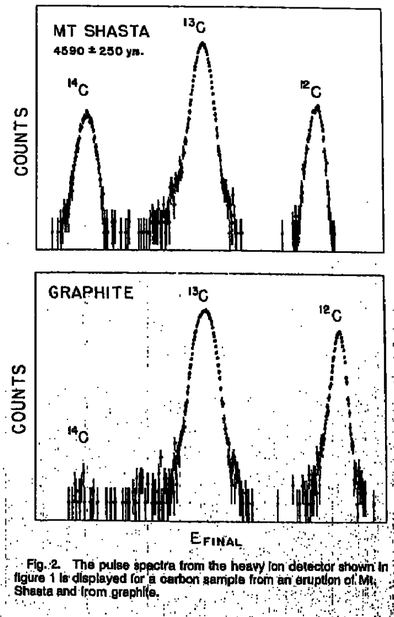

Fig. 2. The pulse spectra from the heavy ion detector shown in figure 1 is displayed for a carbon sample from an eruption of Mt. Shasta and from graphite.

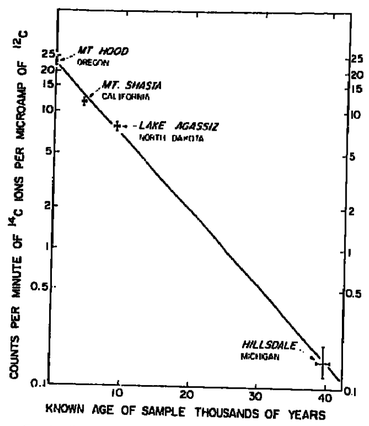

Fig. 3. The logarithm of the ^{14}C counting rate divided by the ^{12}C ion current at the ion source is compared with the known age of the milligram geological samples.

are under construction to extend the work. At present the accuracy of the isotope ratio measurements is being pushed toward 1%, which is quite suitable for dating of small archaeological samples.

3. ^{26}Al has been detected at several laboratories. It is worth noting that the separation of ^{26}Mg is facilitated by the instability of Mg^- and the stability of Al^-. The dating of ocean sediments and ice cores by measuring the ratio of ^{26}Al to ^{26}Be, which would be independent of cosmic ray intensity fluctuations, is now a real possibility.

4. ^{36}Cl in groundwater and meteoritic samples has been extensively studied at Rochester. In this case it is, at present, necessary to purify the samples carefully to remove sulphur because of the presence of ^{36}S, which also forms negative ions readily. Fortunately, ^{36}Ar does not form stable negative ions.

5. ^{129}I has been detected at Rochester by mass spectrometry at levels down to 300 ppq, and it is expected that ^{129}I levels as low as 1 ppq will present no problem in the future. ^{129}I is generated in meteorites by cosmic rays and in the earth's crust by the spontaneous fission on ^{238}U. The ratio $^{129}I/^{238}U$ at equilibrium is near 10^{-11}, which should be easily observable.

6. Recently, stable isotopes of platinum have been observed at below the parts per billion level, and in principle it should be possible to increase the sensitivity further. This establishes the viability of studying heavy masses with ion microprobes such as osmium and rhenium isotopes for dating ore minerals.

The nuclear physics equipment at Rochester, which is used for ultrasensitive mass spectrometry, is unnecessarily large for many such applications. As mentioned earlier, ion energies of about 3 MeV are required to ensure adequate efficiency for generating atoms with three electrons missing. Molecules with three electrons missing fragment very rapidly. As a result of the measurements at Rochester and Oxford universities, some relatively small tandem accelerators and their associated mass spectrometers have been designed so as to be applicable to a wide variety of ultrasensitive measurements.

The complete ultrasensitive mass spectrometers being built by General Ionex for the University of Arizona, Oxford University, and the University of Toronto occupy a space of 6 × 14 m, and a plan view of the device is shown in Figure 4. The system consists of a negative ion mass spectrometer on the left, a 6-m-long molecular disintegrator, an electrostatic analyzer to remove molecular fragments, and a positive ion mass spectrometer with a detector for ion identification and ion counting. The first of these systems will be ready for testing soon.

The system to be installed at the University of Toronto should be in operation in May 1981, and it will be used for a variety of applications.

1. Archaeological and anthropological ^{14}C dating of small samples up to about 60,000 years will be possible with accuracies better than 1%, or 80 years for younger specimens.
2. The $^{26}Al/^{10}Be$ dating of sediments and ice cores over the past 5 million years is being developed.
3. ^{36}Cl and ^{129}I dating of groundwater will be of use in hydrogeological studies.
4. The elimination of molecules should make SIMS studies of minerals easier, and studies with micron size beams will undoubtedly be valuable.

In conclusion, the future of this new frontier of geophysics and physics promises to be quite exciting.

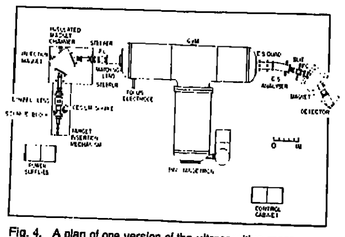

Fig. 4. A plan of one version of the ultrasensitive mass spectrometer being built in various laboratories. Faraday cups are designated FC, and the electrostatic analyzer at the exit of the 3MV tandetron or molecular disintegrator is labeled ES. The generating voltmeter for the measurement of the high voltage is designated GVM.

Acknowledgments

The authors are indebted to K. H. Purser, H. E. Gove, D. W. Strangway, and other colleagues for many contributions to this frontier area of study.

A. E. Litherland, F.R.S., is a nuclear physicist who received his doctorate from the University of Liverpool, after which he moved to Canada to work with Atomic Energy of Canada, Ltd., in Chalk River. There, he measured the spins of nuclear states by observing the angular correlation of particles emerging from nuclear reactions. In 1966 he moved to the Department of Physics, University of Toronto, where he is now university professor. Prior to his involvement in the accelerator-mass spectrometer work, he has concerned himself with low-energy radiative capture in nuclear reactions, electrofission of light elements, and the development of damage track particle detectors.

J. C. Ruckbidge is a mineralogist who took his B.A. from Cambridge University and his Ph.D. from Manchester University. After a spell in cloud physics at the University of Chicago, identifying the mineral particles which form the nuclei of natural ice crystals, he began to use electron microprobe analytical methods in geological problems at Oxford University. In 1965 he continued to develop instrumentation and apply microanalytical techniques to natural materials at the Department of Geology, University of Toronto, where he is now professor. His research has included work on platinum mineralization and details of the alteration processes in ultramafic rocks.

News

Wetlands May Clean Geothermal Water

Development of geothermal resources may help to ease energy problems, but water quality problems could result from the disposal of spent geothermal brines. Research by EG&G Idaho shows that man-made wetlands may provide a more economic disposal system than do conventional treatment and disposal methods.

Most geothermal water contains high concentrations of dissolved solids and trace elements, including fluoride and boron, which can be harmful to water quality and organisms. Because of these high concentrations, only a limited number of methods can be used to dispose of used geothermal water. These include injection wells, evaporation ponds, and disposal into surface waterways.

The treatment proposed by EG&G deposits the spent brine in a small artificial wetland planted with selected aquatic plants such as cattails and duckweed. These plants would remove the chemicals from the water, according to Bob Breckenridge, task manager at the research center at the Raft River Geothermal Experiment Site, near Malta, Idaho. Plants must be harvested regularly, he explained, to prevent decay and the reintroduction of the chemicals into the water. If the plants were burned as an energy source, the fluorides would convert to harmless hydrogen fluoride and would be released into the atmosphere, EG&G said. Fluoride and other chemical residues would be buried in landfill. ⊗

As Comet Halley Approaches

The earliest probable recorded apparition of the comet Halley was 240 B.C., although what could be considered as data gathering on the comet was begun by Johannes Kepler in 1607. Kepler's observational data consisted of visual observation, which started on September 26 of that year and continued through the year, and then again in 1682, 1759, 1835–36, and 1909–11, the last of which was a precise telescopic observation. As we approach the arrival again of comet Halley in 1985, observers on the national scene are calculating the physical behavior to be expected. (*The Comet Halley Handbook: An Observer's Guide Created for the International Halley Watch*, D. K. Yeomans, Jet Propulsion Laboratory, Pasadena, Calif., 1981). A continuing search for the comet's arrival began in November 1977, but was unsuccessful. At that time the magnitude of the comet was estimated to be fainter than 26. When it arrives in 1985 it will be hard to see by the naked eye and probably will only be observed by those who are equipped with telescopes or binoculars and know where and when to observe. It will be necessary to observe outside of populous areas to avoid significant effects of artificial lighting.

The pre-space and post-perihelion close approaches of the comet and Earth will occur on November 27, 1985, and April 11, 1986, at minimum distances of 0.62 and 0.42 AU. Based on observations in years past, the comet's visual tail length appears to be longest after perihelion.

Because of the unfavorable positions of the comet with respect to the earth and the sun on a given date, the comet's observability will depend on the observer's latitude. In general, better observing conditions for the Northern Hemisphere will be available for pre-perihelion positions of the comet, while the post-perihelion observations will be better in the Southern Hemisphere. The following description of observing conditions for comet Halley in 1985–86 is provided in *The Comet Halley Handbook:*

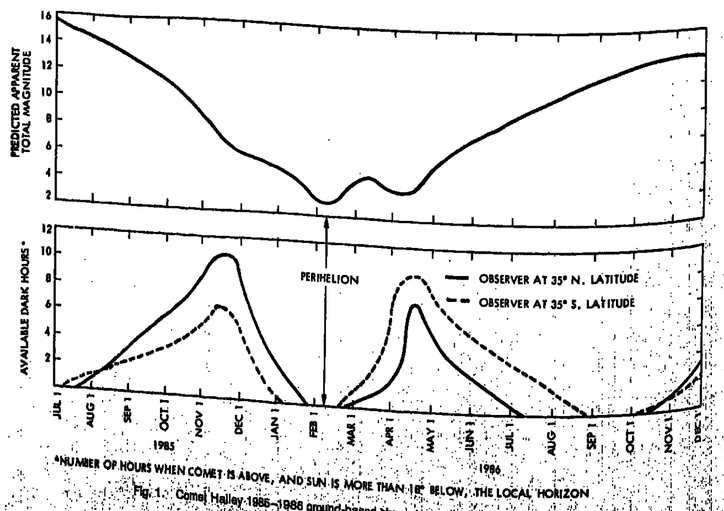

Fig. 1. Comet Halley 1985–1986 ground-based observing conditions.

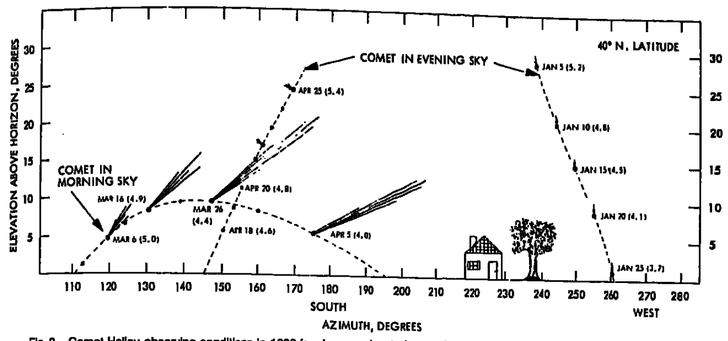

Fig. 2. Comet Halley observing conditions in 1986 for observers located at 40°N latitude. Comet positions are given for beginning of morning astronomical twilight or end of evening astronomical twilight. Approximate total visual magnitudes are given in parentheses following dates. Viewing with binoculars and ideal observing conditions are assumed.

> It is assumed that the comet will be visible to an observer if the comet is above, and the sun is simultaneously more than 18° below, the local horizon. This condition assures that the evening astronomical twilight has ended and morning astronomical twilight has not yet begun (i.e., the comet is seen in a dark sky). The time interval for which this condition holds is referred to as the number of available dark hours. Figure 1 is a plot of the available dark hours vs. calendar date for an observer at 35° north and 35° south latitude. Also plotted in the figure is the total apparent magnitude M_1 vs. calendar date. Figure 2 is a schematic representation as to how comet Halley may appear on various dates for observers located at the latitude of 40° north. The comet's elevation above the local horizon and its azimuth (degrees east of north) are given for the various dates. For each date, the comet's position is given for the end of astronomical twilight, if the comet is in the evening sky, or the beginning of astronomical twilight if the comet is in the morning sky. These positions correspond to times approximately 70–90 minutes after sunset or 70–90 minutes before sunrise. Very rough indications of the comet's tail length and orientation are given for a few representative dates, along with the comet's apparent total magnitude M_1 in parenthesis.
>
> Because the comet occurs once every 76 years, nearly everyone in recorded history has had the opportunity to view it. It may be wise to start planning for this once-in-a-lifetime experience. ⊗

Shuttle Project for Students

Selection of 200 semifinalists has begun for the first national Space Shuttle Student Involvement Project, a joint effort of NASA and the National Science Teachers Association. The semi finalists are being selected from 1500 entries.

Objective of the project is to stimulate study of science and technology in grades 9 through 12. Students compete to develop payload experiments suitable for flight aboard the shuttle. The 1500 entries, grouped into 10 geographic areas, are being reviewed by interdisciplinary teams of teachers, scientists, and engineers. Twenty students from each region will be selected. Ten finalists will then be chosen on their scientific or engineering merit. The 10 national winners and their teachers will attend a special education conference late this summer at the Kennedy Space Center in Florida.

A second contest will open in September, with selection of winners scheduled for May 1982. ⊗

A-21 Compliance

A-21 is the number designation given to an OMB (Office of Management and Budget) directive on cost accounting to universities and other institutions that receive federal research grants. This circular lays down rules for grants. It requires the accounting of a university researcher's work to be made in terms of actual time spent, or in terms of a vaguely defined percent of effort.

Most university professors realize that accountability is actually measured by a group of their peers—the group that eventually decides whether or not to recommend approval and funding for the next proposal or extension. Thus tangible results establish that a scientist has done his proposed job—not his hours (or '% effort'). The OMB accountants want the books to be kept in hours but will accept percent of effort reports.

The real problem arose when OMB included a factor called the 100% reporting requirement. This states that a researcher must account for 100% of his professional time (or effort) in separate categories, including those portions not supported by a research grant. The confirmation of senseless concepts, such as percent of effort (would a professor have to account for his thoughts?), and impossible rules (professors often teach, do research, administrate, etc., all at the same time—and after normal working hours) have led to a sort of cynical compliance by most researchers. With all due respect to careful cost accounting procedures, for a university professor the rules are meaningless, and because the activity breakdowns often cannot be done as required, compliance becomes fabrication. According to D. Allen Bromley of Yale University (*Physics Today*, February 1981), 'University faculty are being forced to give answers that they know are completely meaningless; in effect they are being asked to fabricate a result, and this simply goes against the grain of most people . . . The Federal Government does not own you 100% of your time just because it may support some small fraction of your research.'

This is the first year for implementation of the rules specified in A-21. As the flow of paperwork in the form of activity reports grows, so does the cynicism and protest. Within the National Academy of Sciences, University of Chicago mathematics professor Saunders MacLane has circulated memos and rallied protest. Now the Academy has resolved to disapprove of the accounting rules. It has been proposed that OMB table the new rules until the problems can be addressed, and OMB, while not saying how liberal it will be in enforcing the rules, is taking steps to study the matter. Possibly other reporting methods can be devised, and evidently OMB is open to suggestions.

Most universities are going along with the A-21 rules, but the faculty are none too pleased with the procedures. In a few cases, OMB has allowed postponement of compliance if alternatives can be suggested. Among the suggestions now being tested are those that set statistical samples among the faculty, relieving the rest of the grant-supported professors of the burden. This plan would appear to be an easement of the number of compliances only and not an easement of the rules for those sampled, who must report 100% activity. Aside from the National Academy of Sciences, it appears that Yale University has been a 'center of anti-reporting agitation' (*Physics Today*, v.s.), particularly by its president, A. Bartlett Giamatti, and by mathematics professor Serge Lang. Yale has been invited by OMB to suggest alternatives in time/effort reporting. It seems that a move toward a kind of lock-fund concept, with reference to salary-benefits-overhead may be occurring. The plan to test the notion of a statistical sample for cost accounting may be tried at Stanford and other universities over the next year. Further modification of the guidelines to get around the requirement of reporting of an investigator's total activities would result in a more acceptable system—a system that university grants and contracts were designed for, as opposed to the profit-oriented contracts normally written for industrial research.—*PMB* ⊗

NAS Forms Geological Sciences Board

A new board to help guide geological research has been formed by the National Academy of Sciences' Assembly of Mathematical and Physical Sciences. The 15-member Geological Sciences Board probably will hold its first official meeting in April, according to board chairman William R. Dickinson of the University of Arizona.

The board's formation was spurred by the lack of systematic and continuous attention given to geological sciences in the past and by the increasing contributions geology makes to society, explained Joseph W. Berg, Jr., executive secretary of NAS' Office of Earth Sciences. The board is expected to fill a gap in NAS activities where disciplines such as hydrology, paleontology, and geological engineering have not been represented, Dickinson added. These topics have been handled by ad hoc committees.

What the Geophysics Research Board does for geophysics, the Geological Sciences Board will do for geology. The new board will review and coordinate geological research, help to establish scientific policy, and recommend topics for future research. The board will be an operating board, Berg said. That is, it will determine what geology problems demand attention and will push for action on those problems. However, the board can only recommend.

Topping the list of tasks to be tackled is the establishment of a geologic mapping and data base, Berg said. This basic activity is not complete despite efforts by the U.S. Geological Survey, other boards, and ad hoc geology committees, he explained. 'That human beings construct buildings taller than the depths at which we know geological details is incongruous,' commented Berg.

Other projects with high priority include investigating problems of land use, specifically the siting of dams and nuclear powerplants; studying crustal structure and evolution; assessing mineral deposits; and suggesting the involvement of United States geologists in international projects.

Rotation of board members will follow that of other NAS boards. Members will be appointed to 3-year terms. Nominations for replacements will be taken from academia, government, industry, and professional societies.

Approximately $125,000 will be required to finance the new board, Berg said. Requests for funds have been made to various government agencies, including the National Science Foundation and USGS.—*BTS* ⊗

Menard Steps Down

When a new administration takes over in Washington, it is not unusual at all for top government officials to be replaced. The administration will be held responsible for the success or failure of the federal agencies, so it is logical for a new president, or his close advisors, to approve top-level staff. The level defined as 'high' has been extended, particularly since the days of the Nixon administration, to beyond cabinet and department secretary, reaching broadly to within the structure of federal agencies. The U.S. Geological Survey remained unscathed by political appointments until 1977, when the Carter administration abruptly removed Vincent McKelvey from his position as director. Now, the Reagan administration has followed suit by terminating the appointment of H. William Menard, U.S.G.S. director for the past 4 years under the Carter administration. In both instances, submittal of resignation letters was a courtesy—a formality, but acceptance of their resignations was not. Both McKelvey and his successor, Menard, are professionals, but both were treated politically. These are only the first and second cases of political interference at the U.S.G.S. in over a century. Until these instances, the position of director was held as a purely professional one.

Beyond just a reshuffling of personnel at high levels of government, however, it is important to note that the U.S. Geological Survey's mission has changed markedly in re-

(*News cont. on page 108*)

(News cont. from page 107)

cent years. President Carter's secretary of the interior, Cecil D. Andrus, was widely quoted to the effect that the Survey, and by association, McKelvey, was not oriented toward the administration's views on domestic oil and gas reserves. By the same token, Reagan accused Interior, including the Geological Survey, of 'being more concerned with conserving resources than with exploiting them' (*Science*, February 1981). The new secretary of the interior, James G. Watt, has ousted all the directors and heads of the relevant agencies within the Interior Department in an effort to turn the situation around, at least politically.

There seems to be a set of clear mandates of the new administration that will influence resource-sensitive federal agencies. Nonetheless, as reported in *Science*, it is widely known that the Geological Survey has 'an outstanding record for scientific excellence and professional integrity.' The replacement of personnel at the level of the office of director may continue to be only a part of what *Science* has termed 'wholesale house cleaning.'

Potential candidates to replace Menard may wonder whether such a great personal commitment can or should be made for such a politically sensitive position.—*PMB* ✪

NASA Establishes Speakers Bureau

A Planetary Geology Speakers Bureau has been established to present to universities and other institutions the latest results of solar system exploration and to present colloquia on topics of current interest.

Fifteen lecturers from across the United States comprise the speakers bureau, which was established by NASA's planetary geology program. These speakers can lecture on such topics as Venusian geology, planetary volcanism, lunar geology, the origin of asteroids, Martin geology, Venusian tectonics, comparative planetary geology, the Allende meteorite, comet exploration, the Galilean satellites, and geologic evolution of the terrestrial planets.

The host group or department will be expected to pay the customary expenses associated with the speaker's travel. To schedule a speaker or for more information, contact the Planetary Geology Speakers Bureau, Department of Geology, Arizona State University, Tempe, AZ 85281, or telephone (602) 965-7092. ✪

Geophysicists

George S. Benton, former associate administrator of NOAA, has returned to his professorship in the Department of Earth and Planetary Sciences at the Johns Hopkins University.

Geophysical Events

The following item comprises selected reprints from *SEAN Bulletin*, 6(1), January 30, 1981, a publication of the Smithsonian Institution

Volcanic Activity

Mount St. Helens Volcano, Cascade Range, southern Washington, USA (46.20°N, 122.18°W). All times are local (GMT – 8 h). Lava extrusion resumed February 5, adding a substantial quantity of new material to the dome that grew in the crater after the October 16–18 explosions and the two new lobes produced in late December and early January.

Minor activity—January: After growth of the December-January lobes ceased between January 2 and 4, outward movement of the northern crater rampart gradually declined to an average of about ½ cm/day, although rates were variable and data were limited. January seismicity was the quietest of any period since earthquakes began March 20. Only 40 discrete events were large enough to be recorded on three or more stations of the U.S. Geological Survey-University of Washington seismic net at Mount St. Helens, in contrast to 136 in December and 74 in November. Of the January earthquakes, about 10 were low-frequency events associated with dome growth early in the month, many others were rock avalanche events, and a few accompanied ejection of steam plumes. A new fumarole opened January 9 on the eastern margin of the lava dome. This fumarole was the probable source of small steam and ash plumes on January 16 at 1152 (to 3-km altitude) and January 20 at 1204 (to at least 3 km), both accompanied by bursts of seismicity. Similar seismic activity was recorded January 24–25, and field parties saw light ash deposits on fresh snow. Several similar bursts occurred January 31–February 1, two of which could be correlated with steam and ash emission. However, another steam plume was ejected without accompanying seismicity.

Increased deformation and seismicity: Deformation and seismic activity both began to increase at the beginning of February. Radial fissures in the crater floor began to widen at a noticeably faster rate, and movement of thrust faults accelerated. A larger number of glowing cracks in the surface of the lava dome indicated that its temperature was increasing. On February 2 at 0336, a 4-min burst of seismicity was followed by a magnitude 2 earthquake at 0340, than low-level harmonic tremor was recorded until 0630. Occasional bursts of seismic activity continued through the day, and 35 minutes of low-level tremor was recorded that night. A gradual increase in discrete earthquakes began February 3. Occasional low-level tremor was recorded, as were several bursts of seismicity, one of which was associated with a small plume at 1220. By midnight of the night of February 4–5, the number of discrete events had reached 4 to 5 per hour and continued at this rate for about 6 hours,

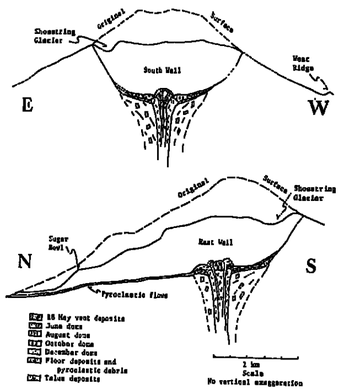

Fig 1. East-west and north-south cross sections through Mount St. Helens. [By Michael Doukas, U.S. Geological Survey, January 1981.]

Lava extrusion: Just before 0500, the U.S. Geological Survey and the University of Washington issued an advisory predicting an eruption within the next 12 hours. Seismicity began to decline about 0600, probably signaling the beginning of lava extrusion. By 0800, earthquakes were occurring at a rate of only about 1 per hour. Very heavy steaming obscured the crater, but new lava could be seen on the October dome during about 30 seconds of visibility. The number of discrete seismic events decreased further by mid-afternoon, remaining at many fewer than 1 per hour through February 8. However, bursts of unusual seismic signals were recorded, possibly caused by lava extrusion.

Improved visibility revealed that the new lava was extruded through the collapse pit in the center of the October dome. The new material appeared to have both uplifted and overridden the October dome, leaving this area about 35 m higher by the time growth apparently stopped during the night of February 6–7. The small northwest lobe, which had been emplaced during the December-January activity, was pushed about 12 m to the north and partially overridden by new lava. New thrust faulting also occurred in the southwest part of the crater, but it was much less extensive than the thrusting associated with the December-January activity. The increase in dome volume produced by the February extrusion was roughly equal to the volume of lava produced by each of the two previous events, but at press time it was not possible to determine how much volume was of new lava on the surface and how much was caused by uplift of preexisting lobes.

Information contacts: Don Swanson, Chris Newhall, and John Dvorak, U.S. Geological Survey Field Office, 301 E. McLaughlin, Vancouver, WA 98663.

Steven Malone, Christina Boyko, Elliot Endo, and Craig Weaver, Graduate Program in Geophysics, University of Washington, Seattle, WA 98195.

Robert Tilling, U.S. Geological Survey, Stop 906, National Center, Reston, VA 22092.

Piton de la Fournaise Volcano, Réunion Island, Indian Ocean (21.23°S, 55.71°E). All times are local (GMT + 4 h). A summit area eruption of Piton de la Fournaise began on February 3 after 12 days of local earthquakes and 17 cm of summit inflation. After a fairly sudden onset of seismicity January 23, about 40 magnitude 2 events were recorded daily by the newly established Volcano Observatory of Réunion. The day before the start of the eruption, 73 earthquakes were recorded, with foci about 1 km beneath Cratère Bory, the smaller of the two summit craters (see Figure 2). Seismicity intensified in the hour prior to the first eruptive activity on February 3. About 250 small discrete events were followed by 5 minutes of harmonic tremor, then at 2030 a small fissure opened in Cratère Bory. A minor lava flow was extruded during 2 hours of activity along this fissure, and a 6-m-high hornito formed at the vent. During the second hour of the eruption, a small amount of aa lava flowed from a vent about 200 m below the rim separating the larger Cratère Dolomieu from Bory. This lava covered about ¾ of a small crater ruin (Enclos Velain) between Bory and Dolomieu.

After about 2 hours, two or three small fissures opened on the northeast side of Cratère Dolomieu, each extruding a lava flow about 100 m long. The next morning at about 0400, a 300-m-long north-south trending fissure formed lower on the northeast side of Dolomieu. Three spatter vents were active initially, but within an hour, fountaining (15–30 m high) was limited to the lower portion of the fissure. Lava flowed downslope through channels and lava tubes onto the caldera floor.

As of early February 6, lava fountaining as much as 70 m high was continuing from a 30-m-long segment of the lower end of the fissure. The activity had built a small, elongated cone with three vents. The lava flow, composed of aphyric basalt, was 1.5–2 km in length and covered several thousand square meters of the caldera floor. Seismicity beneath Cratère Bory had stopped a few hours after the eruption began, but small events were occurring February 6 beneath Nez Coupé de Ste. Rose, on the caldera's northern rim.

This eruption produced more lava than the two most recent previous eruptions, May 28–29 and July 13–14, 1979. However, the 1981 volume is of the same order of magnitude as has been extruded by Piton de la Fournaise in most of its numerous lava flow eruptions from the summit area in the past 50 years.

Information contacts: L. Stieltjes, BRGM, Service Geologique Regional, B.P. 1206, 97484 Saint Denis, Réunion.

Volcano Observatory of Réunion.

Maurice Krafft, Equipe Vulcain, B.P. 5, 68700 Cernay, France.

White Island Volcano, Bay of Plenty, New Zealand (37.50°S, 177.23°E). New Zealand Geological Survey personnel flew routine surveillance over White Island (active since December 18, 1976) on the morning of January 6. In the 10 minutes they were over the island the voluminous convoluting emissions of white steam and gas clouds obscured their view around and into 1978 Crater. The 600-750-m-high eruption column was slightly ash charged in its lower portion. The main crater was thickly covered with eroded brown-green ash. Impact craters could be seen extending a few hundred meters northeast from 1978 Crater. Conspicuous blue fumes were associated with the steam-gas column rising in the 1914 landslide area just southeast of 1978 Crater.

Seismicity since the last ground inspections in early December was characterized by four distinct periods of marked increase. Intervals of high-frequency, high-amplitude tremor were recorded for 32 hours on December 15–16, for 35 hours on December 22–23, and for 26 hours on December 27–28. Strong ash emissions were likely to have occurred during these periods. Large discrete earthquakes were recorded on December 14 and January 2.

CARTE SCHEMATIQUE DES ERUPTIONS DU VOLCAN DE LA FOURNAISE (1972-1973)

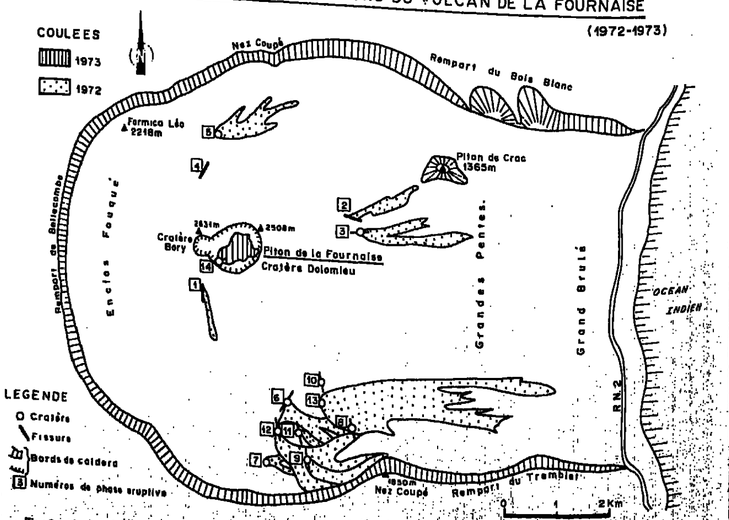

Fig. 2. Map of the caldera of Piton de la Fournaise [From Krafft, M., and A. Gerente: L'activité de Piton de la Fournaise entre Octobre 1972 et Mai 1973, *C. R. Acad. Sci. Paris, Série D*, 284, 607-610, 1977.]

Information contact: B. J. Scott, New Zealand Geological Survey, P.O. Box 499, Rotorua, N.Z.

Krafla Caldera, Mývatn Area, Iceland (65.71°N, 16.75°W). All times are GMT. The following is a report from Karl Grönvold and Páll Einarsson.

Since the eruption from the Krafla fissure swarm in October, Krafla had inflated as before. The previous ground level was reached in late November. A small, slow deflation took place 25–28 December with magma movement toward the N, but no eruption occurred. Inflation resumed, and the ground level at which previous deflation events and eruptions were triggered was again reached about 10 January, but inflation continued.

On 30 January at about 0700, slow deflation of the magma reservoirs started, as recorded by tiltmeters at the Krafla power plant. The rate of deflation rapidly increased and about 0730 tremor appeared on seismometers. Deflation rate and tremor amplitude reached a maximum at about 0900 and declined very gradually thereafter. The earthquake epicenters indicated movement of magma along the fault swarm toward the N. Soon after 1400, a fissure eruption started in the fault swarm 8–9 km N of the center of the magma reservoirs. The fissure soon extended to 2 km length and the lava front quickly moved toward the N. The eruption site is close to those of July and October 1980, and the eruptive behavior is broadly similar. In the morning of 31 January, the fissure had shortened to about 330–400 m, and the lava production rate had decreased somewhat.

The eruption was continuing on 2 February and very slow deflation also continued.

The eruption site is in an uninhabited area and poses no danger to the local population. Observations are hampered due to remoteness and difficult weather conditions.

Information contacts: Karl Grönvold, Nordic Volcanological Institute, University of Iceland, Reykjavik, Iceland.

Páll Einarsson, Science Institute, University of Iceland, Reykjavik, Iceland.

Marion Island Volcano, Prince Edward Islands, Indian Ocean (46.90°S, 37.75°E). The following is from a report by Shaun Russell and Aldo Berruti.

During the first week in November, research station personnel visiting the west side of Marion Island observed two new cinder cones, three small lava flows, and fresh tephra deposits, none of which were present when the scientists were last in the area in February.

Russell and Berruti traveled to the eruption site in late November. Regrowth of burnt vegetation indicated that the activity had probably occurred at least 2 months earlier. The smaller of the two cinder cones, about 6 m high with a crater 15 m in diameter, had formed at the summit of Kaalkopple, an eroded, 100-m-high tuff cone. A lava flow that apparently originated from the west (seaward) flank of the summit cone had poured over nearby cliffs 50–70 m high and ponded in a small amphitheaterlike area at their base. About 10 m of lava remained in the amphitheater in November, but caves above this level were partially filled with lava. Some of the lava had drained from the amphitheater and continued about 100 m seaward, flowing into the ocean and forming a front about 120 m wide and 10 m high. A lava tube seen at the southern edge of this flow in early November had collapsed by the time Russell and Berruti saw it on the 26th, forming a 4-m-wide trench. This flow covered about 2 hectares, including the portion between the summit cone and the cliffs.

A second lava flow occupied a few hundred square meters of the promontory above the amphitheater mentioned above. A small amount of this lava had spilled through a fissure onto the first flow, but most remained on the promontory or poured over its concave northern cliff face into the sea.

On the flank of Kaalkopple, east of the new summit cone and near its base, a larger tephra cone had formed around a 35-m-diameter crater. The east side of the cone was breached by a lava flow, 35 m wide as it emerged from the crater, that eventually reached 50 m width before diverging into two lobes. One lobe flowed about 350 m to the northwest, the second about 200 m to the south along a shallow valley. The total area covered by this flow was about 7 hectares.

Irregular blocks and spheroidal bombs nearly 1 m in diameter were found on the flank cone. Fusiform and ribbon bombs fell as much as 350 m from the cone, with heaviest tephra fall extending from its eastern, breached, side. A continuous layer of ash and lapilli covered an area extending several hundred meters to the east and 40 m south of the two cones, with scattered fragments found 250 m to the south and much farther to the southeast.

No other eruptions have been reported in historic time from Marion Island. Some unvegetated lava flows appear no more than a few hundred years old [*Verwoerd*, 1967].

References

Verwoerd, W. J., Marion and Prince Edward Islands, *Nature*, *213*, 5073, 230–232, 1967.

Information contacts: Aldo Berruti, Percy Fitzpatrick Institute, University of Cape Town, Rondebosch 7700, South Africa.

Shaun Russell, Institute of Environmental Sciences, University of Orange Free State, Bloemfontein 9300, South Africa.

M. D. du Plessis, Geological Survey, Private Bag X112, Pretoria 0001, South Africa.

C. G. Hide, Office of the Scientific Counsellor, South African Embassy, Suite 300, 2555 M St. NW, Washington, DC 20037.

Paluweh Volcano, Lesser Sunda Islands, Indonesia (8.32°S, 121.71°E). All times are local (GMT + 8 h). Activity at Paluweh began to increase on November 5 and continued intermittently through the end of January. On November 9, an eruption column rose 1 km from the summit crater. Bombs fell nearby and 2 mm of ash were deposited 1 km to the west. Bombs and ash were ejected for about 15 minutes, starting at 1115 on November 13, from a summit crater vent 40 m in diameter. The tephra column reached 700 m in height. On January 27, ejecta set bushes afire near a flank village. Detonations from explosions on January 31 were heard at Kota Baru, Flores Island (50–60 km from the volcano) at 0740, 0803, 0807, 0913, 1030, and 1215. No additional activity had occurred as of February 5.

Information contacts: Adjat Sudradjat, Director, and Liek Pardyanto, Senior Volcanologist, Volcanological Survey of Indonesia, Diponegoro 57, Bandung, Indonesia.

Karkar Volcano, off the north coast of New Guinea (4.65°S, 145.96°E). The following is a report from the acting senior volcanologist.

A transient increase in hydrothermal and fumarolic activity for 2 to 3 days at the beginning of December coincided with the onset of seasonal heavy rains. Minor geysers were observed on the floor of 1979 Crater. There were voluminous emissions of white vapour from a landslide on the Bagial side of 1979 Crater floor. Fumarolic activity was strong on the W side of Bagial Cone and on the E side of the caldera floor right up to the caldera wall. Weak to moderate vapour emissions at these localities continued for the rest of the month.

Karkar began an explosive eruption in January 1979. Two volcanologists were killed in March by an explosion from the southeast foot of Bagial Cone.

Information contact: Acting Senior Volcanologist, Rabaul Observatory, P.O. Box 386, Rabaul, Papua New Guinea.

Langila Volcano, New Britain Island, Papua New Guinea (5.53°S, 148.42°E). The following is a report from the acting senior volcanologist.

Vapour emissions continued from Craters 2 and 3. Some small ejections of brown-grey ash rose from Crater 2. The lava flow from Crater 3 was still active and had almost reached the terminus of the 1975 flow.

Langila has been active since 1973.

Information contact: Acting Senior Volcanologist, Rabaul Observatory, P.O. Box 386, Rabaul, Papua New Guinea.

Manam Volcano, off the north coast of New Guinea (4.10°S, 145.06°). The following is a report from the acting senior volcanologist.

Moderate to strong light brown to grey ash-laden vapour and, rarely, dark brown dust were sporadically ejected from the S vent. The main vent occasionally emitted weak white vapour. Light ashfall from the S vent was recorded at nearby Tabele on 2 December. Low rumbling noises were heard on 20 and 25 December. A weak glow was observed at night from the S vent from 26 to 29 December. Seismic activity was at its normal level. Radial tilt remained fairly steady after inflation of about 10 microradians during September and October. Tangential tilt commenced a downward trend showing a fall in level to the E of about 6 microradians.

Manam's current eruption began in 1974.

Information contact: Acting Senior Volcanologist, Rabaul Observatory, P.O. Box 386, Rabaul, Papua New Guinea.

Ulawun Volcano, New Britain Island, Papua New Guinea (5.04°S, 151.34°E). The following is a report from the acting senior volcanologist.

The volcano was very quiet throughout December with only continuous moderate emission of white vapour from the summit crater.

Ulawun had a brief, intense, explosive eruption on October 6–7, 1980.

Information contact: Acting Senior Volcanologist, Rabaul Observatory, P.O. Box 386, Rabaul, Papua New Guinea.

Sakurazima Volcano, Kyushu, Japan (31.58°N, 130.65°E). All times are local (GMT + 9 h). A burst of B-type earthquakes, which began at 0200 on January 18 prompted the Japan Meteorological Agency (JMA) observatory at Sakurazima to issue an explosion warning at 0930. Reflected glow was seen over the summit that night. Four strong explosions occurred during the next 2 days. Each of the first three produced a 200-m-high incandescent column. The fourth strongest explosion at 1632 on January 20 ejected an incandescent block that formed a 1.3-m-diameter crater when it fell near an inhabited area. Similar occurrences of B-type earthquake bursts, reflected glow of the lava mound in the crater, and explosions were observed in July and August 1979.

None of the January explosions caused any damage.

Information contact: Seismological Division, Japan Meteorological Agency, 1-3-4 Otemachi, Chiyoda-ku, Tokyo 100, Japan.

TABLE 1. Explosions at Sakurazima, January 1981

Date	1	2	5	6	8	9	10	14	
Number	1	1	1	1	1	1	1	1	
Date	17	19	20	21	25	28	29	31	Total
Number	1	2	2	1	1	1	1	1	18

Tarumai Volcano, Hokkaido, Japan (42.68°N, 141.38°E). Seismic activity at Tarumai increased again to more than 400 recorded events during January. No eruption has yet been observed. About 200 events per month were recorded in November and December, after over a year of fewer than 50 events per month. The last eruptions occurred in December 1978–May 1979.

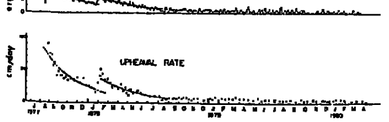

Fig. 3. Discharge rate of seismic energy (ergs/day) from Usu, August 1977–April 1980 (top) and uplift rate (cm/day) of the 'New Mountain' cryptodome (bottom) for the same period. Note the increase in February 1978. [Data are from I. Yokoyama.]

Information contact: Seismological Division, Japan Meteorological Agency, 1-3-4, Otemachi, Chiyoda-ku, Tokyo 100, Japan.

Usu Volcano, Hokkaido, Japan (42.53°N, 140.83°E). Cryptodome uplift and local seismicity continued through 1980 at Usu, site of a major explosive eruption in August 1977. Weaker explosive activity had occurred through October 1978. Since then, gradually weakening steam emission from the vents formed in 1978 has been observed.

Local seismicity continued an irregular decline through 1980 (see Figure 3 and Table 2). Felt shocks averaged 3 per day in 1980, but swarms of 30–40 felt events in a single day occurred about once a month. The earthquakes were caused by subsurface magma movement associated with cryptodome uplift. Careful correlation of seismic records with observed surface deformation and faulting revealed that larger earthquakes occurred simultaneously with measurable fault movements.

TABLE 2. Number of Local Earthquakes per Month, Usu Volcano, January–December 1980

Month	Jan	Feb	Mar	Apr	May	Jun
Recorded events	1176	1004	890	582	673	211
Felt events	234	216	162	92	121	32
	Jul	Aug	Sep	Oct	Nov	Dec
Recorded events	601	486	620	413	604	572
Felt events	112	82	108	69	106	94

The rate of uplift of the 'New Mountain' cryptodome decreased through 1980, from 5 cm/day in January to 3–4 cm/day in December (Figure 4). Northward lateral movement of the northern flank continued at a similar rate. As a result, compression of the ground north of the volcano also continued, affecting several towns and villages.

Information contacts: Seismological Division, Japan Meteorological Agency, 1-3-4 Otemachi, Chiyoda-ku, Tokyo 100, Japan.

I. Yokoyama, Hokkaido University, Sapporo, Japan.

Volcanic Activity in Nicaragua—early 1981. The following is a report from Richard E. Stoiber and Stanley N. Williams.

Scientists from Dartmouth College, the Nicaraguan Institute of Natural Resources and Environment, and the Nica-

(News cont. on page 111)

AGU BOOKSHELF

Majestic Lights: The Aurora in Science, History and the Arts, (1980) R. H. Eather, illustrated, color plates, 324 pages, cloth-bound, $49.00-special member price $29.40 (SP0027)

The aurora is the only visible manifestation of the turbulent magnetic and electrical environment surrounding our planet. Eather's concentrated research into the aural phenomena produces new data published here for the first time. Over 100 color plates show the beauty and variety of the aurora. This authoritative and profusely illustrated book is fully referenced and is the only scholarly treatment of the subject to be published in this century. A valuable textbook and desirable gift.

Indian Ocean Geology and Biostratigraphy, J. R. Heirtzler, editor (1977) 616 pages, $19.00 (SP0019)

Twenty two chapters representing a synthesis of all the work published in the Initial Reports and other related publications for the IPOD Project involving the drilling vessel Golmar Challenger. These articles establish a complete history of the Indian Ocean and rest upon a solid factual basis. A full color supplemental map of the Indian Ocean is available. $10.00

Quantitative Modeling of Magnetospheric Processes (1979) W. P. Olson, 550 pp., $23.00 (GM2100)

This volume provides an annotated list of quantitative models that serves as a reference on energy particle distribution and magnetic and electric models. The magnetic field is discussed as a relatively stable feature of the magnetosphere, and the electric field papers contain descriptions of past, present, and future experiments in the field.

Climatic Changes (1978) M. I. Budyko, translated from the Russian text by Rima Zolina, English text edited by Leonard Levin, 288 pp., $18.00 (SP0016)

Can we and will we manage our global climate of the future by controlling the atmospheric aerosol level? The relationship between physical climatology and climatic changes are of great significance to human life. In the geological records climate has been very variable as the pattern of continents and oceans changed. A well-developed study, easily read, a must for all concerned with human life

Chinese Geophysics: Earthquake Research in China, volume 1, number 1 & 2 (1978), editors T. L. Teng and W. H. K. Lee, 45 pp., $10.00 in paperback

A provocative look at the hitherto unpublished geophysical studies conducted in China 1974-1978. China is earthquake country, with abundant historical seismic records dating back to 1831 B.C. This collection of records, combined with modern macroscopic seismic materials, gives the researcher much new information. It predicts major, as well as minor, quakes by using seismic zones and specified time periods from quiescence to high activity and by showing strain accumulation to rapid strain release.

Scientific Results of the Viking Project (1977), illustrated, foldouts, maps, color plates, 728 pp., $30.00 (SP0020)

The two Viking missions to Mars are NASA's most ambitious and memorable planetary missions to date. From seismology to biology, the scientific range is a record for a planetary technological and exploratory endeavor. Papers reprinted from the *Journal of Geophysical Research.*

The Use of Artificial Satellites for Geodesy (1972), edited by S. W. Henriksen, A. Mancini, and B. H. Chovitz, 298 pp., $28.00 (GM1500)

This monograph contains contributions on geometric geodesy, physical geodesy, instrumentation and environment, and extraterrestrial geodesy. Noteworthy achievements which conquered the problem of achieving decameter accuracy worldwide, significant papers on the fine structure of the earth's potential, and papers on the orbiting gravity gradiometer, satellite altimetry, etc., represent the most recent findings in satellite geodesy.

Birds of the Antarctic and Sub-Antarctic (1975), George E. Watson, 350 pp., $15.00; special AGU member price $10.00 (AR2400).

This informative handbook, with its many beautiful color plates and illustrations by Bob Hines of the U.S. Fish and Wildlife Service, has become a desirable gift item as well as taking its place on the textbook shelf.

Groundwater Management: The Use of Numerical Models (1980), John Bredehoeft, et al, 135 pages, softcover, $5.00, (WM0500).

This monograph has been directed toward the improvement of groundwater management. The recommendations will assist planners in formulating their objectives and, more importantly, that they will serve to increase the benefits from the world's groundwater resources. A must for all those who are concerned with water use.

Plate Tectonics (revised 1980) edited by John M. Bird, 992 pp., illustrated, softbound, $20.00 (SP0026)

A selection of 69 papers from AGU publications which is intended to illustrate the development and broad aspects of plate tectonics. Included is a historical bibliography of over 900 papers published from 1963 through 1979. An invaluable reference tool and a must for classrooms and libraries.

Deep Drilling Results in the Atlantic Ocean: Continental Margins and Paleoenvironment (1979), edited by M. Talwani, W. Hay, and W. B. Ryan, 439 pp., $18.00 (ME0300).
Deep Drilling Results in the Atlantic Ocean: Ocean Crust (1979), edited by M. Talwani, C. G. Harrison, and D. E. Hayes, 446 pp., $18.00 (ME0200).
Island Arcs, Deep Sea Trenches, and Back-Arc Basins (1979), edited by M. Talwani and W. C. Pitman, 480 pp., $18.00 (ME0100).

The Maurice Ewing Series is based on biennial symposia which cover convergent tectonics in a broad spectrum of geophysical and petrologic studies. These volumes are intended to give a survey of current studies in present and past areas of subduction by utilizing multichannel seismic-reflection profiles, heat flow measurements, hypocenter locations, and volcanic rock compositions to bring out the processes and products of plate consumption

World Water Resources and their Future, M. I. L'vovich (1979) 416 pages, $26.00 (SP0022)

English translation edited by Raymond L. Nace. L'vovich's determination of water balances and the water cycle is a means of obtaining a description of water resources and their genesis, of studying their transformation, and of seeking rational ways to use and conserve water. This book should be read by all hydrologists and experts of water use regardless of whether their concern is with local, regional, continental or global problems.

The Geophysics of the Pacific Ocean Basin and Its Margin (1976), edited by G. H. Sutton, M. H. Manghnani, and R. Moberly, 480 pp., $15.00 (GM1900).

Gravity and geodesy, seismology, magnetism, marine geology and tectonics, volcanology and petrology, and tectonophysics, each with its reference to the Pacific area, are reviewed and followed by papers of significance to current areas of research. This book is apt praise to George P. Woollard, to whom the volume is dedicated

Deep-Seated Inclusions in Kimberlites and the Composition of the Upper Mantle (1977) N. V. Sobolev (translated by D. A. Brown, English translation edited by F.R. Boyd), 279 pp., illustrated, $21.50 (SP0014)

Research into the assemblages of inclusions in diamonds and the intergrowth of minerals moves from hypothesis to synthesis in this important study of deep-seated inclusions in kimberlites and their relationship to upper-mantle formation.

Biological Effects of Electromagnetic Waves (1977), edited by D. R. Justesen and A. W. Guy, 293 pp., $25.00 (RS0001)

Radiobiology-radio frequency radiation has just begun to be understood. This volume explores microbiology and physiology, medical biology and teriology, and the central nervous system and behavior. The perspectives gained are not without some very sobering sidelights and indicate many areas where future research must delve.

Derivation, Meaning, and Use of Geomagnetic Indices, (1980), P. N. Mayaud, illustrated, 36 tables, referenced and indexed, 160 pages, hardcover, $20.00 (GM2200).

Mayaud first answers the question, what is a geomagnetic index? Then gives: an historical review of the main indices used in the past and describes the three classes of indices officially recognized by the IAGA at present. This book will aid workers to use the geomagnetic indices and give an understanding of their meaning and of the way in which they are derived. An important and lasting reference tool.

The Upper Atmosphere in Motion (1974), edited by C. O. Hines et al., 1027 pp., $22.00 (GM7800).

Hines' classic papers 'Internal Atmospheric Gravity Waves at Ionospheric Heights' and 'A Unifying Theory of High-Latitude Geophysical Phenomena and Geomagnetic Storms,' the latter written in collaboration with W. I. Axford, are only two of the 44 vital, innovative papers in this textbook collection.

Multiobjective Water Resource Planning (1977), David C. Major, 81 pp., $5.00 softbound (WM0400).

Multiobjective analysis of our water resources frees the planner from the burdens of designing projects that are not fully representative of the social, economic, environmental, and other objectives that govern public investment in our water resources. Of vital interest to all who are interested in water conservation.

Kimberlites, Diatremes, and Diamonds: Their Geology, Petrology, and Geochemistry (1979), edited by F. R. Boyd and Henry O. A. Meyer, 408 pp., $19.00 (SP0024).
The Mantle Sample: Inclusions in Kimberlites and Other Volcanics (1979), edited by F. R. Boyd and Henry O. A. Meyer, 432 pp., $19.00 (SP0025).

The Second International Kimberlite Conference papers cover a variety of research stemming from both the realization that the study of xenoliths and megacrysts provide direct insight into the petrology of the mantle and from the intensive prospecting for diamonds worldwide. A valuable reference source!

Dynamics of Plate Interiors, (1980) edited by A. W. Bally, P. L. Bender, T. R. McGetchin, R. I. Walcott, illustrated, 168 pages, hardcover, $15.00 (GD0100).

An interdisciplinary focus on the movements of the surface and upper part of the earth's interior. It explores the deformation which occurred along narrow belts between the lithospheric plates and leads to an understanding of the earth process where those motions, primarily vertical occurred within the plates, remote from plate boundaries. This is the first volume in the Geodynamic Series, which publishes the final reports of the International Geodynamics program.

The Tectonic and Geologic Evolution of Southeast Asian Seas and Islands, (1980) Dennis E. Hayes, editor, illustrated, foldout map, 334 pages, $25.00, (GM2300).

A cooperative research endeavor between earth scientists in the United States and their counterparts in Southeast Asia continuing the scientific objectives of the 'Studies of East Asian Tectonics and Resources' (SEATER) program. Seismically active marginal and back-arc basins are explored with a focus on aerial land geology. Closely related materials will be found also in the Maurice Ewing Series books.

Rio Grande Rift: Tectonics and Magmatism (1979), edited by R. E. Riecker, 448 pp., $16.00 (SP0023).

A series of modern papers with its focus on fitting major earth structures into an overall scene. Intensive research into the Rio Grande Rift has evolved from one largely unknown to one of the best documented continental rifts in the world. This endeavor has become a fine example of interdisciplinary research.

The Earth's Crust and Upper Mantle (1969), edited by Pembroke J. Hart, 735 pp., $5.00 softbound (GM1300).

The enthusiasm of The Upper Mantle Project, an international program of geophysical, geochemical, and geological studies concerning the 'upper mantle and its influence on the development of the earth's crust,' encourages the reader to make a personal contribution to the solution of some of the many unsolved problems of the earth's interior.

Man-Made Lakes: Their Problems and Environmental Effects (1973) edited by W. C. Ackermann, G. F. White, and E. B. Worthington, 847 pp., $30.00 (GM1700).

Artificial lakes are symbols of economic advancement and also of dismay. They provoke issues of public judgment that are likely to appear wherever drastic changes are made in an ecosystem. This book researches these issue systems; biological, ecological, environmental, and sociopolitical impacts; and offers alternatives and recommendations.

Antarctic Snow and Ice Studies II (1971), edited by A. P. Crary, illustrated, 412 pp., $24.00 (AR1600).

Glaciological results of major traverses in Antarctica, covering a continuous profile of approximately 4500 km. Elevations, annual snow accumulation, ice thickness, gravity, magnetic field values, and seismic studies form the core of this interdisciplinary venture.

(News cont. from page 109)

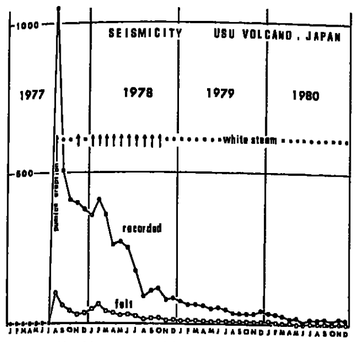

Fig. 4. Monthly averages of the number of recorded (solid circles) and felt (open circles) seismic events per day at Usu, August 1977–December 1980. Explosive activity during a particular month is indicated by arrows.

raguan Institute of Seismic Investigations observed Nicaraguan volcanos during a 3-week period in January and early February 1981.

Masaya (11.95°N, 86.15°W): The gas emission event that began in fall 1979 continued with a steady release of very large amounts of SO_2. Strong winds carried the gas plume onto populated areas at high elevations. A day of notable rockfall activity in the crater was followed for 1 day by a significantly larger rate of gas release.

San Cristóbal (12.70°N, 87.02°W): The gas plume released essentially continuously since gas emission began in 1971 has become intermittent. Periods of energetic gas release of less than 1-hour duration were separated by periods (measured in hours) of only low fumarolic release. Shallow seismic activity continued at levels above background.

Telica (12.60°N, 86.87°W): A small-volume plume of vapor was intermittently released. Shallow seismicity was regularly observed in the vicinity.

Momotombo (12.42°N, 86.55°W): A small, continuous vapor plume was visible. No shallow seismicity was observed around Momotombo.

Information contacts: Richard E. Stoiber and Stanley N. Williams, Department of Earth Sciences, Dartmouth College, Hanover, NH 03755.
Debbie Reid de Jerez, IRENA, Managua, Nicaragua.
Douglas Fajardo, IIS, Managua, Nicaragua.

Earthquakes

Date	Time, GMT	Magnitude	Region
Jan 4	1447	4.2m_b	western Greenland
Jan 18	1817	6.7 M_s	near east coast of Honshu, Japan
Jan 19	1511	6.8 M_s	West Irian, Indonesia
Jan 23	0458	6.1 M_s	Hokkaido, Japan
Jan 23	2114	7.0 M_s	Sichuan, China
Jan 23	2155	7.1 M_s	Atlantic-Indian Rise
Jan 30	0853	6.9 M_s	Rat Islands, Aleutians

Latitude	Longitude	Depth of Focus
76.92°N	67.33°W	shallow
38.69°N	142.83°E	40 km
4.60°S	139.30°E	shallow
42.85°N	142.15°E	shallow
30.97°N	101.14°E	22 km
29.73°S	60.75°E	10 km
51.57°N	176.39°E	shallow

The west Greenland earthquake caused small cracks and displacements around Thule and as much as 125 km to the south southeast at Savigsivik. The January 18 event registered 2 on the Japanese Meteorological Association scale in Yokohama and was felt in northern Honshu and southern Hokkaido. The West Irian shock, and landslides triggered by it, killed 261 persons and caused much destruction in the Jayawijaya Mountains, on the southern edge of the central highlands. The January 23 Japanese earthquake was the second and strongest of three that day on Hokkaido. It was felt from the Kurile Islands to Tokyo, but no serious damage was reported. The Chinese earthquake on the same day in the Dawu district of Sichuan province killed fewer than 150 persons but caused extensive damage to dwellings and roads. The January 30 event centered near the Rat Islands was widely felt throughout the western Aleutians, though only lightly on Shemya Island 160 km to the west.

Information contacts: V. F. Buchwald, Department of Metallurgy, The Technical University of Denmark, Building 204, 100 Lundtoftevej, 2800 Lyngby, Denmark.
Tokiko Tiba, Department of Geology, National Science Museum, 3-23-1 Hyakunin-cho, Shinjuku-ku, Tokyo 160, Japan.
National Earthquake Information Service, U.S. Geological Survey, Stop 967, Denver Federal Center, Box 25046, Denver, Colorado 80225 USA.
Agence France-Presse.
United Press International.

Fireballs

Western Austria, December 28, 1980, 221814 GMT. The following is a report from Zdeněk Ceplecha.

A fireball of −13 maximum absolute magnitude was photographed by several Czech and German stations of the European Fireball Network. The fireball traveled a 27 km trajectory in 1.3 seconds. The following preliminary results are based on the first four available photographs from distant stations (330 to 460 km away).

	Beginning	Maximum Light	Terminal
Velocity (km/s)	22	21	18
Height (km)	92	79	69
Latitude	48.95°N	47.02°N	47.07°N
Longitude	10.85°E	10.59°E	10.55°E
Magnitude	−4.2	−12.6	−4.5
Mass (kg)	29	18	none
Z R	33°	33°	33°

Fireball type: III B
Meteorite fall impossible.

Radiant (1950.0)	Observed	Geocentric	Heliocentric
Alpha	99°	99°	—
Delta	17°	15°	—
Lambda	—	—	40°
Beta	—	—	−5°
Initial Velocity (km/s)	22.4	19.3	35.5

Orbit (1950.0)

A	1.8 A.U.
E	0.63
Q	0.59 A.U.
Aphelion	2.8 A.U.
Omega	91°
Ascending node	98.98°
Inclination	5°

Information contact: Zdeněk Ceplecha, Ondřejov Observatory, 251 65 Ondřejov, Czechoslovakia.

Burma, November 2, about 1130 GMT (about 1800 local time). Elizabeth Crowder saw a brilliant fireball just after sunset from Pagan, about 200 km southwest of Mandalay on the Irawaddy River. Walking southwest along an unlit street, she noticed the sky brighten as if a street light had been turned on behind her. She turned and observed a brilliant fireball with a rounded red and blue head and a long, yellow, arc-shaped tail. The object moved from almost directly overhead toward the northeast, illuminating the sky like a large lightning bolt. It disappeared above the horizon without a terminal explosion. No sounds were associated with the fireball, which was visible for 5–10 seconds.

Information contact: Elizabeth Crowder, 133 Mapache Drive, Portola Valley, CA 94025.

West Germany, December 23, 2047 GMT.
Observers: Capt. Bruns and F/O Rauff of Lufthansa flight LH 263 (Vienna–Dusseldorf)
Location: 15 km NW of Erlangen (40 km NW of Nürnberg), aircraft course 315 magnetic, altitude 9.5 km
First sighting: 045 magnetic, 10 above the horizon
Last sighting: 035 magnetic, at the horizon
Duration: 1s
Apparent brightness: As bright as the full moon
Color: Green/yellow-white
The fireball first appeared as a green line, then separated into three yellow-white 'stars.'
Information contact: Gerhard Polnitzky, Universitaets-Sternwarte, Tuerkenschanzstrasse 17, A-1180 Wien, Austria.

New Zealand, October 17, 1980, 2242 GMT (18 October, 1042 New Zealand Standard Time). Mr. and Mrs. T. D. Wenborn reported that while they were sitting on the beach at Ruby Bay, near Nelson, at the north end of South Island on Tasman Bay, they noticed a vivid white trail forming behind an invisible object moving at great speed. The trail extended from the east northeast side of the zenith back to the east northeast horizon. In 3 seconds the object traveled to 45° above the west southwest horizon, where it was lost in cloud. There was no sound during the passage overhead, but only 3 or 4 seconds later they heard a muffled dull explosion. The Wenborns remained on the beach for another 15 minutes, then continued their trip northwest. After driving for 10 or 15 minutes they observed the end of the trail. It terminated in a cloud like structure with five or six similar trails leading from it.

No other observers are known. The DSIR Geological Survey branch had no seismic record of the event. Air Traffic Control at Wellington showed no aircraft in the vicinity during this period. Lincoln Tempero, Naval Attaché, New Zealand Embassy, Washington, D.C., reported that no military maneuvers were underway. The New Zealand Meteorological Service is researching weather conditions at this time.

The Meteor Section of the Royal Astronomical Society of New Zealand is investigating the event and will provide more details when they are available.
Information contacts: Ken I. Morse, Director, Meteor Section, Royal Astronomical Society of New Zealand, P.O. Box 2241, Wellington, New Zealand.
Lincoln Tempero, Naval Attaché, New Zealand Embassy, 37 Observatory Circle, Washington, DC 20008.

Oman, January 20, 2028 GMT
Observers: Capt. Habegger and F/O Moser of Swissair flight SR 197 (Bombay–Athens)
Location: 23.90°N, 57.25°E, aircraft course 280° magnetic, altitude 8.5 km
First sighting: 200° magnetic, 10° above the horizon
Last sighting: 200° magnetic, at the horizon
Duration: 1 s
Apparent brightness: Dazzling
Color: White/blue
The fireball appeared as point without a tail, first white, then blue. There was no flickering.
Information contact: Gerhard Polnitzky, Universitaets-Sternwarte, Tuerkenschanzstrasse 17, A-1180 Wien, Austria.

Western Pennsylvania, USA, 1 January, 1810 GMT (1310 Eastern Standard Time). A daylight fireball and a loud explosion occurred over western Pennsylvania on New Year's Day. The pilot of TWA flight 83 reported to Cleveland Air Traffic Control at Oberlin, Ohio, that he was at 9.5 km over the Somerset, Pennsylvania, FAA beacon and was seeing a 'ball of flames, like magnesium on fire' falling straight down in front of him. Two other airline pilots reported similar sightings to Cleveland when they entered Cleveland's air space about 20 minutes later: to the northwest from over Martinsburg, West Virginia (Northwest Orient flight 69), and to the north of Pittsburgh from over Charleston, West Virginia (Eastern flight 140). A general aviation pilot reported later in the day that he had seen a fireball about 1310. There were no sightings from the ground because a heavy snow storm was in progress.

The explosion was heard and felt about 1315 over a region from Allegheny County north to Warren County. Seismic effects included vibrations, ground shaking, and cracked windows. The North American Air Defense Command (NORAD) had predicted no reentries for this time and location. Paul Oles, program director of the Buhl Planetarium and Institute of Popular Science in Pittsburgh, suggested that a 'fragile meteorite' might have fallen. No meteorite pieces have been reported recovered.

Information contacts: Don Anderson, Cleveland Air Traffic Control Center, Oberlin, OH.
Paul Oles, Program Director, Buhl Planetarium and Institute of Popular Science, Allegheny Square, Pittsburgh, PA 15212.
NORAD/OPI, Peterson AFB, CO 80914.
United Press International.

New Publications

Glossary of Geology, 2nd Ed.

R. L. Bates and J. A. Jackson (Eds.), American Geological Institute, Falls Church, Virginia, x + 749 pp., 1980, $60.00.

Reviewed by Rhodes W. Fairbridge

A review of a glossary can hardly follow the usual lines for a monograph or textbook. The authorship is multiple, though strongly edited, and the style is inevitably dry and the organization is alphabetic. (In terms of subjects, essentially randomly.) I cannot claim to have read it cover to cover.

Nevertheless, it is a superb volume, and every serious earth scientist will have to possess his or her own copy. The price is a bit steep, but that's how the costs are running these days. This is called a second edition. The first A.G.I. Glossary was in 1957, covering 14,000 odd terms. A paperback selection appeared later. In 1972 came a completely new work with 33,000 terms; now the present volume, a rigorous revision, which by strict discipline and close editing has been kept down to 36,000. Notable expansion has been in such areas as plate tectonics, paleomagnetism, seismic stratigraphy, and remote sensing. Another 450 new mineral names appear, adding to some 4000 already recorded.

The scope of the glossary is geology and geophysics in the broadest connotation and reaches the interfaces with archeology, astrogeology, climatology, oceanography, and soil science. Dipping into the book generates a salutary sense of awe. What a vast science we have generated. In spite of the impressive recent advances in quantitative data acquisition and analysis, the great bulk of earth science must be verbally described. Some of the terms are remarkably disarming. You may snigger, if so inclined, over 'coal smut' or be envious over 'hog wallow.' And what is 'lumpy'? (It is a badly cut gemstone.) If you deal in earth history, you should not confuse 'lower' with 'early.' Acronyms, at least 100 of them, range from MSL to the LVL. Geodesists will miss RVCM (recent vertical crustal movements). Some rather controversial terms are treated with varying agility. 'Geosyncline' fares much better than 'geocline.' Various laws, familiar and otherwise, also get mixed attention: Stoke's Law and Sternberg's Law do fine, but Snell's Law needs a bit of help (students of beach erosion really need this). Some extraordinary and unexpected synonyms emerge: thua, 'orthid' is both a kind of soil and a family of Paleozoic brachiopods; I guess you would tell which by the context. And 'geo-' of course means anything to do with the earth, but 'geo' (no hyphen) means a chasm in Old Norse. I counted exactly 100 'geo-' words before getting 'geoid,' which would be a good 'datum' on which to close.

But as an afterthought, by the way, if you enjoy guessing games, each of the alphabetic heads is accompanied by an untitled 'geo-' photograph. If there is an earth scientist who can identify the whole lot, A through Z, I'll be happy to buy him or her the drinks (no cheating now, there is a list somewhere). I'm sure we will all join the devoted editors, Julia Jackson and Bob Bates, in saying 'Thank You,' and hope with them that the glossary will prove to be 'a bulwark against the babelization of the geological language.'

Rhodes W. Fairbridge is with the Department of Geological Sciences, Columbia University, New York, New York.

New Listings

Items listed in New Publications can be ordered directly from the publisher; they are not available through AGU.

Advances in Geophysics, vol. 22, *Estuarine Physics and Chemistry: Studies in Long Island Sound*, B. Saltzman (Ed.), Academic, New York, xiv + 424 pp., 1980, $44.50.

American Geological Literature, 1669 to 1850, R. M. Hazen and M. H. Hazen, Academic, New York, xii + 431 pp., 1980, $32.00.

Catastrophic Flooding: The Origin of the Channeled Scabland, V. R. Baker (Ed.), Dowden, Hutchinson & Ross, Inc., Stroudsburg, Pa., xiii + 360 pp., 1981, $40.00.

Earthlike Planets: Surfaces of Mercury, Venus, Earth, Moon, Mars, B. Murray, M. C. Malin, R. Greeley, W. H. Freeman, San Francisco, Calif., xiv + 387 pp., 1981.

Geodesy, 4th ed., G. Bomford, Clarendon, Oxford, xii + 855, 1980.

Hot Dry Rock Geothermal Energy Development Program, G. M. Cremer, R. B. Duffield, M. C. Smith, and M. G. Wilson (Eds.), Los Alamos Scientific Laboratory, Los Alamos, N.M., viii + 248 pp., 1980.

Map of Significant Earthquakes 1900–1979, National Geophysical and Solar-Terrestrial Data Center, Boulder, Colo., 1980. Available from NOAA, Boulder, Colo.

Physical Oceanography of the Tropical Atlantic during GATE, W. Duing, F. Ostapoff, J. Merle, Kingsport Press, Kingsport, Tenn., x + 117 pp., 1980.

Classified

EOS offers classified space for Positions Available, Positions Wanted, and Services, Supplies, Courses, and Announcements. There are no discounts or commissions on classified ads. Any type that is not publisher's choice is charged for at display rates. EOS is published weekly on Tuesday. Ads must be received in writing on Monday 1 week prior to the date of the issue required.

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POSITIONS AVAILABLE

Structural Geologist. The Department of Geosciences of Purdue University invites application for a tenure track faculty position in structural geology, starting in August 1981. Rank and salary will be commensurate with qualifications. A Ph.D. is required. The individual will be expected to teach undergraduate and graduate courses in structural geology and tectonics, participate in summer field courses and pursue an active research program. Preference will be given to a candidate with an applied field orientation and a strong background in the quantitative analysis of field data. The department has active programs in petrology, geophysics, and engineering geology and has a close working relationship with the geotechnical group in civil engineering and the Laboratory for Applications of Remote Sensing. Closing date for application is April 1, 1981. Applicants should send a resume, the names, addresses, and telephone numbers of three referees, and a brief statement of research interests to R. H. McCallister, Department of Geosciences, Purdue University, West Lafayette, IN 47907.

Purdue University is an equal opportunity/affirmative action employer.

Solid Planet Geophysicist/Texas A&M University. The Department of Geophysics at Texas A&M University is pleased to announce availability of a junior level tenure track faculty position. The department emphasizes solid earth geophysics with concentrations in tectonophysics, geodynamics and internal structure. We are seeking a talented and active researcher and teacher who will complement, strengthen, and broaden current areas of expertise. There are excellent opportunities for interaction and collaboration with members of our department as well as those in the departments of oceanography and geology and in the center for tectonophysics. Qualified scientists are requested to send resumes to Neville L. Carter, Head, Department of Geophysics, Texas A&M University, College Station, TX 77843.

Texas A&M University is an equal opportunity employer.

South Dakota School of Mines & Technology. The Department invites applications for a postdoctorate position in either (1) magnetic stratigraphy paleomagnetism of coal bearing strata; (2) precambrian stratigraphy economic geology related to low-grade metasedimentary rocks of the Black Hills, SD. The appointment is for 12 months beginning in summer 1981.

For further information write or call Alva Lisenbee, Dept. of Geology and Geol. Engr., South Dakota School of Mines & Technology, Rapid City, SD 57701 (605-394-2461).

South Dakota School of Mines is an equal opportunity/affirmative action employer.

Research Officer in Radiocarbon Research: Research School of Earth Sciences/Environmental Geochemistry Group, The Australian National University. The Environmental Geochemistry Group is currently using geochemical, stable isotope and radiochemical methods to study the geochemical evolution and palaeoclimatology of the Great Barrier Reef, Australian inland lakes and the Gulf of Carpentaria. Applications are invited from scientists specialising in radiocarbon research to undertake collaborative studies in these projects and in aspects of Holocene palaeoclimatology and the carbon cycle.

The appointee will normally be attached to the ANU Radiocarbon Laboratory and will work in collaboration and co-operation with its Head, H. Polach, and its staff. The appointee will be responsible for the expansion of the laboratory to meet the increased needs of the R.S.E.S. Environmental Geochemistry Program.

He She is expected to independently conduct this research program, including the processing and counting of samples, and to contribute academically to their analysis, interpretation, and publication.

The appointment will be for three years in the first instance with the possibility of a continuing appointment after review. Appointment would be at the level of Research Officer Grade 1 although an appointment at Research Officer Grade 2 level would be considered for an appropriate applicant.

Salary on appointment will be in accordance with qualifications and experience within the following limits:

Research Officer Grade 1: $15,300–$19,125 p.a.

Research Officer Grade 2: $19,864–$23,622 p.a.

Further details of the post are available from Dr. W. Compston, Research School of Earth Sciences.

Reasonable appointment expenses are paid. Return fares may be available to an appointee from overseas who holds a limited term appointment and assistance with accommodation will be provided to the successful applicant. The appointee will be required to undergo a medical examination.

Written applications, quoting reference number 81142, should be forwarded to the Secretary, The Australian National University, P.O. Box 4, Canberra A.C.T. 2600, with whom applications close on 24 April 1981. Receipt of applications will not be acknowledged unless requested.

The University reserves the right not to make an appointment or to make an appointment by invitation at any time.

Hydrogeologist. Applications invited for a permanent faculty position. The position requires a Ph.D., teaching at graduate and undergraduate levels, supervision of research, and research in area of specialty. Interaction with faculty in surface water hydrology, stable-isotope geochemistry, geophysics, and sedimentary geochemistry is expected.

Candidates should send resume, statement of research interest, and addresses of three references to L. D. McKinney, Chairman, Department of Geology, Northern Illinois University, DeKalb, IL 60115.

An equal opportunity affirmative action employer.

Seismologist. The Department of Geology at the University of Illinois, Urbana-Champaign, has an opening for a tenure track position at the assistant professor level, beginning during the 1981–82 academic year. A Ph.D. is required. The applicant should have a strong background in geology, and post-doctorate experience is desirable. Candidates with interests and experience in tectonic studies based on seismological observations will be given preference. The successful candidate is expected to develop an active research program to complement existing programs in geodynamics, solid earth geophysics, and rock physics. There is also opportunity for interaction with programs in the Department of Theoretical & Applied Mechanics and Civil Engineering, and the Interdisciplinary Materials Research Laboratory. Send resumé and names of three references to: Dr. John Hower, Head, Department of Geology, University of Illinois, 245 Natural History Bldg., 1301 W. Green St., Urbana, IL 61801 (Telephone: 217/333-3542). Applications should be received by April 15, 1981.

The University of Illinois is an affirmative action/equal opportunity employer.

Mineralogist/Geochemist. Position open to perform routine and research activities associated with a project to determine the environmental acceptability of stabilized coal waste in the sea. Must have experience in cementation reactions, optical microscopy; SEM and X-ray diffraction. MS degree in chemistry, materials science, geochemistry or equivalent experience. Send three letters of recommendation and resume to: Dr. Iver W. Duedall, Marine Sciences Research Center, SUNY Stony Brook, Stony Brook, NY 11794.

SUNY Stony Brook is an equal opportunity/affirmative action employer.

Exploration Geophysicist/University of Oklahoma. The School of Geology and Geophysics at the University of Oklahoma will hire an experienced exploration geophysicist to fill the Frank and Betty Schultz Professorship, and is seeking nominations and applications for the position. The person must be a distinguished scientist who has made important contributions to exploration geophysics through research. Preference will be given to a scientist whose specialty is seismic properties of earth materials and who has earned the Ph.D. The Schultz Professor will provide leadership and guidance in establishing a quality teaching and research exploration geophysics group. The University of Oklahoma has recently made a strong commitment to the earth sciences with the establishment of a College of Geosciences, to be housed in a new building. The School of Geology and Geophysics will expand from its present faculty of 16 to 25 faculty members by 1986. This will include three scientists in the exploration geophysics area, five in structure-tectonophysics-solid earth geophysics and others in stratigraphy-paleontology, geochemistry-petrology, and energy resources.

Applications are due April 30, 1981. Inquiries, nominations, and applications should be sent to John Wickham, Director, School of Geology and Geophysics, University of Oklahoma, Norman, OK 73019.

The University of Oklahoma is an equal opportunity employer.

Northern Arizona University. Tenure track position in the department of physics. Presently planning early implementation of a masters degree program in atmospheric science. Candidate expected to contribute to research program. Teaching may be in undergraduate physics program as well as atmospheric science. Assistant or associate professor level. W. R. Willis, Box 6010, Northern Arizona University, Flagstaff, AZ 86011.

Stanford University and San Jose State University: Atmospheric Sciences/Research Associate. Applications are invited for a position as research associate which will be available in June 1981. This position involves development of a three dimensional numerical planetary boundary layer model of the fate of large point source plumes in a coastal urban environment. Interested candidates with modeling experience and possessing the Ph.D. in atmospheric science, meteorology, or related areas are invited to submit a curriculum vitae and references to: Prof. Robert Street, Department of Civil Engineering, Stanford University, Stanford, CA 94305 or Prof. Robert Dornstein, Department of Meteorology, San Jose State University, San Jose, CA 95192.

Both universities are equal opportunity/affirmative action employers.

Economic Geologist. The Department of Geoscience at New Mexico Institute of Mining & Technology wishes to add staff members in the field or ore deposits and/or energy resources, petroleum structural geology and geomorphology remote sensing. Applications with expertise in any of these fields will be considered but preference will be given to those with proven capabilities in economic geology. If successful, candidates will be expected to develop an active research program in addition to participating in instruction. Rank open. Send resumes, three references and statement of research interest and plans to: Dr. A. J. Budding, Chairman Search Committee, Geoscience Department, New Mexico Institute of Mining & Technology, Socorro, NM 87801. Closing date March 31, 1981.

AA/EOE.

Sedimentary Geologist/Micropaleontologist, Washington University. The Department of Earth and Planetary Sciences, Washington University, has available a tenure track, assistant professorship position, beginning in the 1981–82 academic year for a geoscientist with research interests in diagenesis of sediments or in micropaleontology.

The successful candidate must have the following attributes: demonstrated creativity and promise of excellence in research and teaching; intent to develop a vigorous graduate research program; desire to teach courses in field of interest and related fields of geoscience at undergraduate and graduate levels.

Send resume, statement of future research interests, and names of at least three references, to Larry Haskin, Chairman, Department of Earth & Planetary Sciences, Washington University, St. Louis, MO 63130. Applications received through April 15, 1981.

Washington University is an equal opportunity/affirmative action employer.

Theoretical Meteorology. The Swiss Federal Institute of Technology in Zurich invites applications for a faculty position in theoretical meteorology. Responsibilities of the new professor include teaching and research in dynamical and boundary layer meteorology. The successful applicant will have a Ph.D. or equivalent education, a strong record of successful research and teaching experience. Applications should be submitted before April 30, 1981, to the President, Swiss Federal Institute of Technology, ETH-Zentrum, CH-8092 Zurich.

Faculty Position University of Iowa. The Department of Physics and Astronomy anticipates one or two openings for tenure track faculty in August 1981. Research specialties for which substantial resources are available are magnetospheric and auroral physics and space and laboratory plasma physics, both theoretical and experimental. Other specialities of interest are astronomy, astrophysics, elementary particle physics, atomic physics, condensed matter, and low energy nuclear physics. The positions involve undergraduate and graduate teaching, guidance of research students, and personal research. Interested persons should send a résumé, a statement of research interests, and the names of three professional references to Search Committee, Department of Physics and Astronomy, University of Iowa, Iowa City, IA 52242.

The University of Iowa is an equal opportunity/affirmative action employer.

Battelle, Pacific Northwest Laboratories. Applications are invited for a postdoctoral position in geophysics with emphasis on middle or upper atmospheric research at the Battelle Observatory in Richland, Washington. Stipend will be $18,000 initially; the position offers the possibility of a permanent research position at the end of the postdoctoral appointment. Address inquiries to R. A. Stokes, Battelle Observatory, Battelle, Pacific Northwest Laboratories, P.O. Box 999, Richland, WA 99352.

Faculty Position in Oceanography/Geology University of Northern Colorado. The Department of Earth Sciences invites applications for a full-time, tenure track faculty position in oceanography, starting September 1981. We are seeking a person with a broad background in oceanography and one or more of the related earth science fields such as marine geology and/or sedimentology. Major responsibility will be teaching beginning and advanced courses in oceanography, courses in the related field, and general education courses. A modest amount of research is possible and is encouraged. Applicants should possess the Ph.D. degree or be in the final stages of completion of that degree. Starting rank and salary will depend on experience and other qualifications of the candidate selected.

Applicants should submit a resume and at least three letters of recommendation to Dr. L. Glen Cobb, Chairman, Department of Earth Sciences, University of Northern Colorado, Greeley, CO 80639.

The deadline for application is May 10.

Postdoctoral and Graduate Research Assistant Positions/Environmental Chemistry. The Department of Environmental Systems Engineering at Clemson University has available graduate research assistantships and two postdoctoral positions for research in acid deposition, trace metal geochemistry, and fate of trace organics in the environment. Contact A. W. Elzerman, ESE-Rhodes, Clemson University, Clemson, SC 29631 (803-656-3276).

Clemson University is an equal opportunity/affirmative action employer.

Research Assistant Professorr CSU. Special initial appointment is for one year with possibility of extension beyond that period. This is a 12-month full time appointment where the successful applicant is expected to engage full time in research. Applicant will be given the major responsibility to conduct and direct research in a group actively involved in both basic and applied research on conjunctive management of surface and groundwaters. A recent Ph.D. with a background in hydrology, groundwater hydrology, or systems hydrology. A strong interest or experience in flow through porous media, transport of dissolved contaminants as applied to groundwater systems and numerical analysis techniques is desired.

Application deadline is April 15, 1981. Position available April 30, 1981. Salary is negotiable.

Send resume, graduate transcripts and names of references to Dr. Hubert J. Morel-Seytoux, Chairman of Search Committee, Department of Civil Engineering, Colorado State University, Fort Collins, CO 80523, (303) 491-8549 or (303) 491-5448.

CSU is EEO/AA employer. E.O. Office: 314 Student Services Building.

Assistant Professor in Atmospheric Science-climate dynamics.

Qualifications: Ph.D. in atmospheric science or related field with strong background and evidence of experience in the theory, phenomenology, and numerical modeling of atmospheric motion systems and a demonstrated interest in the study of climate and its physical basis.

Teaching responsibilities include: numerical prediction course and sharing in teaching of one or two other undergraduate course in basic and applied theory and phenomenology and one graduate level course.

Research focus is on climate, its energetics and dynamics. These studies would complement existing projects involving hydrologic cycles, regional evapotranspiration, trace gas transport and air pollution effects.

Applicants should submit resume, transcripts, copies of publications, and the names and addresses of at least three references to: Dr. Bryan Weare, Search Committee, Department of Land, Air, and Water Resources, University of California, Davis, CA 95616, by May 15, 1981.

The University of California is an equal; opportunity/affirmative action employer and invites applications from all qualified individuals.

Physical Oceanographer. The Department of Marine Science and Engineering, North Carolina State University, has an immediate opening for a postdoctoral research associate. Research will be directed toward equatorial circulation dynamics, including seasonal and higher-frequency variability. Participation in fieldwork will be required. Qualifications include a Ph.D. or equivalent in physical oceanography or geophysical fluid dynamics and experience in the analysis of oceanographic time series. The initial appointment will be for 2 years, with a possible continuation subject to availability of funds. Salary is competitive and negotiable, based upon qualifications. Applicants should send the names of three references, a resume, and publication list to Robert H. Weisberg, Department of Marine Science and Engineering, P.O. Box 5923, NC State University, Raleigh, NC 27650.

Head: Earth Resources Branch, NASA/Goddard Space Flight Center. GS-1330-14/15: $37,871–$50,112 per annum, full-time permanent. The Earth Survey Applications Division, Applications Directorate, NASA/Goddard Space Flight Center invites applications for the open position of Head, Earth Resources Branch. The incumbent of this position is responsible for planning, managing, and conducting broad programs in earth resources remote sensing basic and applied research and data analysis, emphasizing the development and demonstration of applications of remote sensing of earth resources from earth orbiting satellites. The primary areas of research in the Branch are land use management, vegetation sciences including agriculture/forestry/rangeland and environmental monitoring utilizing remotely sensed data and advanced technologies. Also, significant effort is dedicated to sensor data evaluation in terms of applications and scientific utility, and to specification of data acquisition and information extraction systems which best meet user scientific and resource management needs. An advanced degree in earth or physical sciences is required with education in the vegetation sciences, land use or environmental monitoring being specifically preferred. Candidates should also have several years of progressively more responsible experience in the conduct, guidance and management of remote sensing research programs and clear evidence of a strong research background indicating senior research scientist stature.

Resumes/SF 171's should be sent to:
Dr. Robert D. Price, Assistant Chief
Earth Survey Applications Division
Code 920
Goddard Space Flight Center
Greenbelt, MD 20771
Deadline for applications is April 30, 1981.

Von Braun Post-Doctoral Fellowship in Space Physics/University of Alabama in Huntsville. Appointment effective September 1981 in a tenure track assistant professorship with reduced teaching load during the first two years. Research capability in astrophysics, planetary science or solar terrestrial physics. Research support available from UAH, NASA and Redstone Arsenal. Salary competitive. Recent Ph.D.s are invited to send resume, research plans and names of four references. Apply to: Von Braun Fellowship Committee, Office of Academic Affairs, University of Alabama in Huntsville, AL 35899.

Equal opportunity in education and employment.

Physical Science. Tenure track assistant professor to teach physical science, geoscience and energy courses for non-science majors starting fall 1981. Background in physics and geoscience preferred. Applicants must have a well defined interest and experience in teaching non-science majors. A Ph.D. and an active interest in research is also required. Send curriculum vitae, three letters of reference, and a summary of research interests and needs by May 22 to R. Nackoney, Chairman, Department of Natural Science, Loyola University, Chicago, IL 60626.

EO/AAE.

Research Fellow Aqueous Solution Geochemistry. The Australian National University invites applications for appointment to the position of research fellow—aqueous solution geochemistry, in the Research School of Earth Sciences from those holding a Ph.D. degree in a relevant field.

The Research School of Earth Sciences has recently established an interdisciplinary research group in environmental geochemistry. Current areas of research include application of stable isotope studies and radiochemistry, to the geochemical evolution of the Great Barrier Reef, the Gulf of Carpentaria and the geochemical record contained in the sediments of Australian inland lakes. Special attention is also being devoted to holocene paleoclimatology and the carbon cycle. This group wishes to appoint a research fellow specializing in aqueous solution geochemistry to work on a collaborative basis on research projects in the above areas.

In addition to participating in collaborative research programs, the appointee will have the opportunity of pursuing independent research in general areas of interest to the group. The geochemical environment of Australian inland lakes and groundwaters is of particular interest and the appointee should be prepared to participate in a major research program aimed at understanding the solution, transport and precipitation of chemical species in heterogeneous aqueous solutions and sediments. A wide range of evaporate minerals are known to occur in these basins at the present time.

Consequently, the research undertaken by the successful applicant may have implications not only to environmental geochemistry and palaeoclimatology but also to economically significant topics such as the mobilization, fixation and migration of metals and other elements of economic significance.

Applicants should have broad interests in geochemistry, together with a strong background in theoretical solution geochemistry and relevant experimental-chemical techniques. In addition to describing their qualifications, applicants are invited to submit research proposals detailing the general research directions and specific projects which they would wish to pursue. Further information concerning the position can be obtained directly from Dr. W. Compston.

Salary on appointment will be in accordance with qualifications and experience within the range. Research fellow $19,132–$24,972 per annum. Appointment will be for 2 or 3 years in the first instance with the possibility of extension to five years. Superannuation, housing assistance, reasonable appointment costs.

The University reserves the right not to make an appointment or to make an appointment by invitation at any time. No fixed closing date is specified for the above position.

Interested candidates are requested to submit their applications to The Registrar, Australian National University, PO Box 4, Canberra, ACT 2600, Australia.

Research Plasma Physicist. Must be eligible for Ph.D. in plasma physics with specialization in and abstracts essential on theory and numerical simulations of magnetic sheer effects on instability phenomena as applied to ionospheric and magnetospheric problems. 1 year work experience in the field is required. Position opening in D.C. area. Salary $24,416 per yr., 40 hrs. per wk. Please report with ad to Virginia Employment Commission, 6320 Castle Place, Falls Church, VA, and refer to job order no. 348643.

Senior Hydrogeologist. Fred C. Hart Associates, an environmental consulting firm, is providing technical assistance to the U.S. Environmental Protection Agency in their efforts to discover and identify hazardous waste sites, evaluate their impacts and design site clean-up measures.

An opening exists for the position of senior hydrogeologist in our Newark, N.J. office. The successful candidate will have field and management experience in groundwater contamination and will be responsible for developing monitoring programs and alternative solutions to contamination problems.

Candidates should possess an M.S. degree with five years field experience in hydrogeology, or B.S. degree and seven years field experience in groundwater contamination studies. Please forward resume to: Fred C. Hart Associates, Inc. 155 Washington Street, Newark, N.J. 07102, Att: Amelia J. Janiez.

Research Associate. Position available July 1 for new Ph.D. scientist in climatology-glaciology. Work involves research in ice-climate synoptic interactions based on analysis of satellite imagery and digital data (Nimbus and DMSP systems) of climatological and cryospheric parameters using multivariate statistical techniques. Research is performed in a cooperative university/government laboratory employing scientists engaged in interdisciplinary work related to the environment.

Position requires experience in analysis and display of remote sensing data and in data processing; demonstrated ability to write scientific reports; background of glaciological-meteorological field research in polar areas; experience in interpretation of snow cover, sea ice, and cloud conditions from visible, IR, and ESMR microwave imagery and digital data; experience with multivariate statistical analysis techniques, especially as applied to meteorological or related data; experience in FORTRAN programming in a CDC Kronos or NOS operating environment; and research experience in synoptic climatology and ice-climate interactions.

Salary approximately $17,000/year. Applications including vitae and three references should be addressed to Dr. R. G. Barry, CIRES, Campus Box 449, University of Colorado, Boulder, CO 80309.

The University of Colorado is an equal opportunity/affirmative action employer.

Petrology/Geochemistry, University of New Brunswick. The Department of Geology has a tenure track position available from 1 July, 1981, at assistant professor or higher level. The successful applicant will be expected to teach both undergraduates and graduates as well as carrying out research and supervising graduate students. This position is in addition to one currently advertised for a rock mechanic or geochemist.

The applicant should have a background in petrochemistry and petrology and should be prepared to teach in some aspects of petrology and geochemistry. The successful applicant will be responsible for supervision of analytical facilities including an X.R.F.

Applicants should have a Ph.D. and preferably, post doctoral experience. Applications including a curriculum vitae and names of three referees should be sent to P. F. Williams, Chairman, Department of Geology, University of New Brunswick, Fredericton, N.B. E3B 5A3.

Geophysicist. Applications invited for a tenure track position at the assistant or associate professor level, beginning August 1981. Successful candidate will be expected to develop graduate courses in area of expertise and to teach undergraduate geophysics. Although all areas of geophysics will be considered, preference will be given to professionals with teaching and research interests in seismic stratigraphy and petroleum exploration.

Departmental equipment includes a refraction seismograph, resistivity meter, gravimeter, magnetometer, porometer, and permemeter. The candidate will have the opportunity to substantially add to his or her equipment needs.

Present computer facilities include a DEC 10 and an IBM 360-44, while a PK 3240 system with 16 megabytes capacity is under development.

ODU is a state-supported university serving nearly 15,000 students and is situated within the seventy Hampton Roads metropolitan area that is nationally known for its historic, recreational, and cultural facilities.

Salary commensurate with experience and qualifications. Send vitae, a brief discussion of research interest, and arrange to have three letters of reference by April 10, 1981 to Dennis A. Darby, Chairman, Department of Geophysical Sciences, Old Dominion University, Norfolk, VA 23508.

An affirmative action/equal opportunity employer.

Faculty Position in Physical Oceanography. The Department of Marine, Earth and Atmospheric Sciences at North Carolina State University invites applications for a nine-month, hard money, tenure track position at the assistant or associate professor level for a physical oceanographer, specializing in the numerical modeling of oceanic flows.

Applicants should have a strong background in geophysical fluid mechanics and the abilities to develop a funded research program and graduate level courses. Presently funded areas at NCSU include estuarine, coastal and deep-water oceanography.

Send curriculum vitae and the names of three references by March 31, 1981 to Professor G. S. Janowitz, Chairman, Search Committee in Physical Oceanography, Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, P.O. Box 5068, Raleigh, NC 27650.

North Carolina State University is an equal opportunity/affirmative action employer.

Purdue University. A tenure track appointment in the area of surveying and mapping. Undergraduate teaching in the areas of basic surveying, adjustment computations, and introductory photogrammetry/photo interpretation; involvement in teaching graduate level courses, and in existing and new research programs.

Preferential consideration to candidates with a Ph.D. and land surveying registration (or in the process of getting such degree and registration); rank and salary are open and depend on the experience and qualifications of the applicant.

Send resumes, by 15 April 1981, to Head, School of Civil Engineering, Purdue University, West Lafayette, IN 47907.

Purdue is an equal opportunity/affirmative action employer.

Director Meteorology Division, Air Force Geophysics Laboratory. Air Force Geophysics Laboratory invites applications for the position of Director of the Meteorology Division located at Hanscom Air Force Base, Massachusetts. The Division is responsible for Air Force research and development in meteorology, atmospheric physics, remote and direct sensing technology, climatology, and relative technologies. The division director provides overall direction to an R&D program which employs over 80 people and covers a broad range of in-house and contractual scientific investigation. A candidate should have a record of distinguished achievement in meteorology/atmospheric physics as a research scientist and manager of a substantial R&D unit. This position is Air Force Senior Executive Service with a salary range of $52,247 to $57,673, subject to current $50,112 ceiling. For an application package, call collect: Robert Eisrin, (617) 861-2888. To be considered, applications must be returned by 30 April 1981.

Equal employment opportunity employer.

Research Associate: Colorado State University. The Department of Civil Engineering, Colorado State University, Hydrology and Water Resources Program, invites applications for a position as research associate. The initial appointment is for two years with the possibility of extension beyond that period.

The applicants must have an M.S. with a background in hydrology, groundwater hydrology, or water resources. An interest in the areas of flow through porous media, stream-aquifer interaction, and groundwater modeling is desired. Preference given to persons with experience or strong interest in numerical analysis techniques and modeling using digital computers.

The successful applicant will become a member of a research group actively involved in both basic and applied research on conjunctive management of surface and groundwaters.

Application closing date: April 15, 1981. Position available April 30, 1981. Salary is negotiable.

Send application with resume, graduate/undergraduate transcripts, and names of two references to Dr. H. J. Morel-Seytoux, Chairman of Search Committee, Department of Civil Engineering, Colorado State University, Fort Collins, CO 80523, (303) 491-8549 or (303) 491-5448.

CSU is EEO/AA employer. E.O. Office: 314 Student Services Building.

Chemical Oceanographer. Research associate, M.S., marine organic geochemistry and its relation to ocean productivity. Cooperative Institute of Marine and Atmospheric Sciences, University of Miami and National Oceanic and Atmospheric Administration, contact Chairman Search Committee, D. K. Atwood, NOAA/AOML, 15 Rickenbacker Causeway, Miami, FL 33149

Faculty Appointment/Colorado State University. The Department of Earth Resources, Colorado State University invites applications for a tenure track appointment with emphasis on active research experience in remote sensing, and an interest in teaching graduate and undergraduate students beginning September 1981. The candidate is expected to have a Ph.D. degree in geology, watershed sciences or in a related field and is expected to develop and maintain a vigorous research program with special emphasis on the application of state-of-the-art remote sensing techniques to the investigation of natural resource phenomena. The candidate is expected to teach undergraduate and graduate courses in the application of remote sensing to natural resources.

Rank and salary are open and dependent on experience and qualifications of the applicant.

Applicants are invited to submit curriculum vitae, three letters of reference and a letter describing research and teaching interests to Dr. H. S. Boyne, Department of Earth Resources, Colorado State University, Fort Collins, Colorado 80523/(303) 491-5298.

Deadline for receipt of applications is April 15, 1981.

CSU is an EOE/AA. E.O. Office: 314 Student Serv. Bldg.

Faculty Position/Synoptic Meteorology. The University of Maryland invites applications from qualified scientists for a tenure track faculty position at the assistant or associate professor level, commencing fall 1981. Candidates must have a Ph D in meteorology or related areas and have an area of specialization in synoptic and dynamic meteorology. Teaching experience is desirable. The successful candidate will be expected to teach primarily graduate level courses in synoptic meteorology and carry on an active research program. Salary will be commensurate with qualifications and experience.

All applicants should send curriculum vitae, a brief statement of research interests and names, addresses and telephone numbers of three professional references to: Professor Ferdinand Baer, Chairman, Department of Meteorology, University of Maryland, College Park, Maryland 20742. Closing date for applications is April 15, 1981.

The University of Maryland is an equal opportunity/affirmative action employer.

Faculty Opening. The Department of Geological Sciences of the State University of New York at Albany invites applications for a tenure track faculty position which will be available from September 1, 1981 at the assistant professor level for a research oriented scientist to join a department with strengths in structural geology, tectonics, geochemistry and petrology. Applications are invited from geologists, geophysicists and geochemists with Ph D. degrees who feel qualified to complement or augment studies in these fields. Salary will be negotiable. Letters should be addressed to: Professor Kevin Burke, Chairman, Department of Geological Sciences, c/o Personnel Department, State University of New York at Albany, Albany, N.Y., 12222.

SUNY at Albany is an equal opportunity/affirmative action employer. Applications from women, minorities and handicapped are especially welcome.

COURSES

MSA Short Course on Kinetics of Geological Processes. The Mineralogical Society of America will sponsor a short course in Kinetics of Geological Processes, prior to the 1981 AGU Spring Meeting in Baltimore, Maryland. This short course, organized by Tony C. Lasaga and R. James Kirkpatrick, will be held from May 22-24. Speakers and topics to be included are: Introduction to Rate Theory-Global Kinetics-Geochemical Cycles, Antonio Tony Lasaga, Pennsylvania State University; Irreversible Thermodynamics in Petrology, George Fisher, Johns Hopkins University; Diffusion, David Anderson, University of Illinois; Transition State Theory and Defect Structure of Silicates, Tony C. Lasaga, Pennsylvania State University; Kinetics of Nucleation and Growth in Igneous Processes, R. James Kirkpatrick, University of Illinois; and Kinetics of Weathering and Diagenesis, Robert Berner, Yale University. For additional information and registration forms, contact MSA, 2000 Florida Avenue, N.W., Washington, D.C. 20009 (telephone: 202/462-6913). Registration deadline: March 31, 1981.

Ground Water Modeling. Workshops in Ground Water Modeling are scheduled to be held this spring at the Holcomb Research Institute, Butler University, Indianapolis, Indiana. The workshops feature the Institute's *International Clearinghouse for Ground Water Models*, which stores over 380 computer annotations of ground water models throughout the world. The workshops, co-sponsored by the National Water Well Association, range in complexity from basics in computer modeling to adaptation of the Prickett/Lonnquist Model.

Dates for the 1981 workshops are as follows: Part I: An Introduction to Modeling Ground Water Flow and Transport, May 27–29; Part II: Mathematical Foundations and Computer Implementation of Ground Water Modeling, June 1–5; Part III: Analytical Ground Water Modeling, May 18–22; Part IV: Adaptations of the Prickett/Lonnquist Model, June 8–12.

Instructors for Parts I and II are Drs. James Mercar and Charles Faust, GeoTrans, Inc., P.O. Box 2550, Reston, Va., 22090, Telephone (703) 435-4400. Instructors for Parts III and IV include Thomas A. Prickett, Special Consultant to Camp Dresser and McKee, Inc., and William Walton, Camp Dresser and McKee, 302 E. John St., Suite 1700, Champaign, IL, 61820, Telephone (217) 384-4374.

For more information on course content, contact instructors. For more information on workshop accommodations, logistics, etc., contact Annabelle Paul or Richard Hyde, Holcomb Research Institute, Butler University, Indianapolis, In., 46208, Telephone (317) 283-9555 by April 30, 1981.

Course No. 401: Inversion Methods in Remote Sensing, Alexandria, VA. MAY 18–22, 1981. The course is intended to provide a basic understanding of the concepts and an overview of applications of the increasingly important field of inversion methods in remote sounding and is structured to benefit those involved in the theoretical, experimental, data analysis, and management aspects of remote sensing experiments to monitor the atmospheric constituents and properties from ground, airborne, or space platforms. The advantages, limitations, and future prospects of each technique will be discussed. Instructors will be Drs. M. Chahine, B. J. Conrath, A. Deepak, B. M. Herman, W. L. Smith, D. H. Staelin, and E. R. Westwater. Registration fee is $460.00.

A Certificate of Course Completion will be awarded to those who complete each course. For further information, contact: Nancy Reynolds or Sue Crotts, Course Coordinators, IFAORS, P.O. Box P, Hampton, Virginia 23666 (Tel: 804/827-5811).

SERVICES

Geophysical Historian. A historian of geophysics, specializing in seismic investigation of the Upper Mantle and preparing state-of-the-art reviews on particular questions in this field. Has a doctoral degree from the USSR Academy of Sciences Institute for the History of Science and Technology. Was a senior editor and researcher at the Soviet Geophysical Committee in Moscow. Has written a monograph, many articles in her field, as well as edited over 60 books. Contact E. Millutina, 111 Elmwood Street, apt. 5E, New York City, NY 10040.

Meetings

Understanding Basin Hydrology

A symposium on the understanding of hydrologic processes at the basin scale will be held at the Universidad Simón Bolivar in Caracas, Venezuela, January 11–14, 1982. The aim of the symposium is to assess the present understanding and to explore new research avenues for climate-basin interaction, hydrologic response, coupling of geomorphology and hydrology, parameterization of hydrologic processes, and robustness of catchment modeling.

The symposium will be convened by the university's graduate program in hydrology and water resources in cooperation with the International Association of Hydrological Sciences.

For additional information, write to Ignacio Rodriguez-Iturbe, Universidad Simón Bolivar, Apartado Postal 80.659, Caracas 1081, Venezuela. ✇

Basaltic Magmatism and Volcanism

A meeting to discuss the Generation of Major Basalt Types will be held at the University of Iceland in Reykjavik, August 15–22, 1982. Basaltic magmatism and volcanism (both oceanic and continental) will be discussed at the meeting, which is cosponsored by the International Association of Volcanology and Chemistry of the Earth's Interior and the International Association of Geochemistry and Cosmochemistry. Emphasis will be on the petrology and geochemistry of the mantle, trace elements, and isotopes. Short field excursions are planned for before and after the meeting.

Registration and abstracts of papers to be presented should be received by May 1, 1982.

For additional information and registration forms, write Basalt Meeting, c/o G. E. Sigvaldason, Nordic Volcanological Institute, 101 Reykjavik, Iceland. ✇

Satellite Doppler Positioning

The Third International Symposium on Satellite Doppler Positioning has been scheduled for February 8–12, 1982, at the Physical Science Laboratory at the New Mexico State University in Las Cruces. The meeting is cosponsored by the Defense Mapping Agency, the National Ocean Survey, and AGU.

For information about the symposium, write Richard Peat, Defense Mapping Agency, Hydrographic-Topographic Center, 6500 Brooks Lane, N.W., Washington, DC 20315. ✇

International Mars Colloquium

The Jet Propulsion Laboratory and the California Institute of Technology will host the Third International Colloquium on Mars, in Pasadena, Calif., August 31–September 2. Cosponsors are NASA, the Lunar and Planetary Institute and the Division of Planetary Sciences of the American Astronomical Society.

Announcements will be sent to all scientists known to be active in planetary investigations. Requests for information from others should be addressed to Conway W. Snyder, Jet Propulsion Laboratory, Pasadena, CA 91109. Information in the colloquium's agenda will be published in July.

The organizing committee includes Arden L. Albee, Raymond E. Arvidson, Joseph M. Boyce, Donald L. Devincenzi, Fraser P. Fanale, Ronald Greeley, Garry E. Hunt, Thomas B. McCord, Robert E. Murphy, Roger J. Phillips, James B. Pollack, Conway W. Snyder, and Joseph Veverka. ✇

Rainfall and Runoff Modeling

The International Symposium on Rainfall-Runoff Modeling will be held at Mississippi State University May 18–21. Planned for discussion are review of present models, directions for future research, and complementary elements of seemingly different modeling approaches.

Among the topics to be covered are hydrologic data, stochastic modeling of stream flow, evapotranspiration modeling, linear modeling of watershed runoff, flood routing, watershed sediment yield, modeling in forest and urban environments, and analysis of hydrologic extremes. Approximately 200 technical presentations are anticipated.

For additional information contact Vijay P. Singh, Director, International Symposium on Rainfall-Runoff Modeling, Department of Civil Engineering, Mississippi State University, P.O. Box Drawer CE, Mississippi State, MS 39762 (telephone: 601/325-3050). ✇

AGU Congressional Science Fellowship

The individual selected will spend a year on the staff of a congressional committee or a House or Senate member, advising on a wide range of scientific issues as they pertain to public policy questions.

Prospective applicants should have a broad background in science, be articulate, literate, flexible, and able to work well with people from diverse professional backgrounds. Prior experience in public policy is not necessary, although such experience and/or a demonstrable interest in applying science to the solution of public problems is desirable.

The fellowship carries with it a stipend of up to $25,000 plus travel allowances.

Interested candidates should submit a letter of intent, a curriculum vitae, and three letters of recommendation to AGU. For further details, write Member Programs Division, Congressional Fellowship Program, American Geophysical Union, 2000 Florida Avenue, N.W., Washington, D.C. 20009.

Deadline: March 31, 1981.

ASSEMBLY TRAVEL

Third Scientific Assembly, International Association of Meteorology and Atmospheric Physics, August 17–28, 1981, Hamburg, Germany

Fourth Scientific Assembly, International Association of Geomagnetism and Aeronomy, August 3–15, 1981, Edinburgh, Scotland

Universal Travel Service, Inc., of Washington, D.C., has been selected as official travel agent for these two assemblies. Contact Anna Monat, Universal Travel Service, Inc., 1825 Connecticut Avenue, N.W., Washington, D.C. 20009 (telephone: 202/667-3202) as soon as possible, indicating your requirements. Every effort will be made to obtain the best schedule and the lowest air fares available, such as super-APEX or group fare.

APEX (advance purchase excursion fare) must be booked 21 days in advance; minimum 7 days, maximum 180 days; $50.00 penalty for any change after ticket is issued. A limited number of seats set aside on each air carrier for this low fare.

Group fare: minimum 40 passengers traveling together, may return individually; tickets issued 21 days in advance. For those attending both assemblies, effort will be made to obtain suitable flights and fares.

From home city to New York (JFK) there are special add-on fares and, in some instances, super saver or published super-APEX fares that can be used in conjunction with transatlantic flight.

Northwest Airlines has direct service from New York to Glasgow (Prestwick). Pan American has daily service from New York to Hamburg; Northwest, twice weekly.

If possible, the group fare, which is the lowest fare, will be used to have 40 passengers traveling over on the same date.

IAGA/Edinburgh

August 1	JFK/Prestwick	NW #38	depart 7:20 PM	arrive August 2	8:00 AM
August 16	Prestwick/JFK	NW #39	depart 1:10	arrive same day	4:50 PM

Super-APEX: $549.00 Group: $526.00

IAMAP/Hamburg

August 15	JFK/Hamburg	PAA #104	depart 9:45 PM	arrive August 16	12:00 noon
August 29	Hamburg/JFK	PAA #101	depart 9:05 AM	arrive same day	12:35 PM
August 14	JFK/Hamburg	NW #30	depart 6:15 PM	arrive August 15	9:30 AM
August 29	Hamburg/JFK	NW #31	depart 12:50 PM	arrive same day	5:25 PM

Super-APEX: $575.00 Group (only on NW): $530.00

First class and regular economy fares are available

Travel Grants to IAGA and IAMAP Scientific Assemblies

Deadline for Applications: April 1

AGU has received from the National Science Foundation grants to assist the travel of individual U.S. scientists to the Fourth Scientific Assembly of the International Association of Geomagnetism and Aeronomy, to be held in Edinburgh, Scotland, August 3–15, 1981, and the Third Scientific Assembly of the International Association of Meteorology and Atmospheric Physics, to be held in Hamburg, Germany, August 17–28, 1981. Application forms for the grants are available from

Member Programs Division
American Geophysical Union
2000 Florida Avenue, N.W.
Washington, D.C. 20009
(Telephone: 202/462-6903).

MEETING ANNOUNCEMENT

LUNAR AND PLANETARY INSTITUTE TOPICAL CONFERENCE

PROCESSES OF PLANETARY RIFTING

December 3-5, 1981
San Francisco Area

CONVENERS: B.H. Baker and P. Morgan
SESSIONS PLANNED:

1) Speculations as to the origin and development of rifts
2) Constraints on rift evolution - setting
3) Constraints on rift evolution - geological development
4) Constraints on rift evolution - physics and chemistry of the lithosphere
5) Resources associated with rifting
6) Our state of ignorance and its remedy

Attendance will be limited to 60 participants. Send applications to attend with brief, but specific outline of potential contributions to the meeting; include a provisional title if you plan to submit an abstract. Abstracts should be submitted to Rift Meeting, Projects Office, Lunar and Planetary Institute, 3303 NASA Road 1, Houston, Texas 77058, USA. Deadline for applications is May 29, 1981. Further information may be obtained from the above address, or phone (713) 486-2150.

Sedimentology Congress Slated for 1982

The 11th International Congress on Sedimentology, sponsored by the International Association of Sedimentologists (IAS), is scheduled for August 22–28, 1982, at McMaster University in Hamilton, Ontario.

Among the topics to be covered at the meeting are Archean sedimentology, deposition and diagenesis of evaporites, low-temperature geochemistry, geomorphology of depositional landforms, environmental sedimentology, sedimentology and plate tectonics, deep-sea sediments, and deep burial diagenesis and maturation of organic matter.

More than 30 field excursions are planned, and they are listed in the first circular. For additional information about the field trips and the congress, write IAS Congress 1982, Department of Geology, McMaster University, Hamilton, Ontario L8S 4M1, Canada. ✇

Mechanical Behavior of Salt

A special conference on the Mechanical Behavior of Salt will be held November 9–11 at The Pennsylvania State University. The conference is sponsored by the university's Rock Mechanics Laboratory in the Department of Mineral Engineering.

Tentative plans are to devote a large proportion of the program to the topic of laboratory testing of salt, including a review of current testing methods and the development of models that describe mechanical behavior. Designing storage caverns and stability monitoring is also an agenda topic.

Chairmen for the conference are H. Reginald Hardy, Jr., director of the Penn State Rock Mechanics Laboratory, and Michael Langer, Bundesanstalt für Geowissenschaften and Rohstoffe, Hannover, West Germany.

For additional information, contact Hardy, Rock Mechanics Laboratory, Room 117 Mineral Sciences Building, The Pennsylvania State University, University Park, PA 16802. Participation in the conference is restricted to persons who are actively involved in the field. ✇

Geophysical Year

(Boldface indicates meetings sponsored or cosponsored by AGU.)

1981

March 19–20 Tectonics and Ore Deposits Symposium, Tucson, Ariz. Sponsor, Arizona Geological Society. (John Reinbold, Conferences and Short Courses, Univ. of Arizona, 1717 E. Speedway Blvd., Tucson, AZ 85721.)

March 23–24 **Space Science Comes of Age: Perspectives in the History of the Space Sciences,** Washington, D.C. (Rita Bobowski, Public Affairs Officer, National Air and Space Museum, Smithsonian Institution, Washington, DC 20560).

March 23–27 International Symposium on Quality of Groundwater, Noordwijkerhout, The Netherlands. Sponsors, Unesco, World Health Organization, Commission of European Communities, International Association of Hydrogeologists, IAHS. (ISQG '81 c/o Kivi, P.O. Box 30424, 2500 GK The Hague, The Netherlands.)

March 24–26 Symposium on the Cerro Prieto Geothermal Field of Baja California, Mexico, San Francisco, Calif. Sponsors, U.S. Department of Energy, Commission Federal de Electricidad of Mexico, Univ. of California, Lawrence Berkeley Laboratory. (Werner Schwarz, Univ. of California, Lawrence Berkeley Laboratory, Earth Sciences Division, Berkeley, CA 94720.)

April 5–10 **Chapman Conference on Generation of the Oceanic Lithosphere,** Airlie House, Warrenton, Va. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

April 6–10 Second International Symposium on Flow: Its Measurement and Control in Science and Industry, St. Louis, Mo. Sponsors, American Society of Mechanical Engineers, Instrument Society of America, National Bureau of Standards. (Prof. William Durgin, Alden Research Laboratories, 30 Shrewsbury St., Holden, MA 01520.)

April 8–10 International Symposium on the Hellenic Arc and Trench, Athens, Greece. (Prof. S. S. Augustithis, International Symposium on the Hellenic Arc and Trench, National Technical Univ., Department of Mineralogy-Petrography-Geology, P.O. Box 1006, Athens, Greece.)

April 14–15 National Water Conservation Conference—Publicly Supplied Potable Water, Denver, Colo. Sponsor, EPA. (National Water Conservation Conference, c/o Enviro Control, Inc., P.O. Box 827, Rockville, MD 20851.)

April 14–16 1981 Symposium on the Effect of the Ionosphere on Radiowave Propagating Systems, Alexandria, Va. Sponsors, Naval Research Laboratory, Air Force Geophysics Laboratory. (F. D. Clarke, NRL Code 4181, 4555 Overlook Ave., Washington, DC 20375.)

April 28–30 Symposium on Multidisciplinary Studies on Hudson/James Bay, Guelph, Ontario, Canada. Sponsor, Univ. of Guelph. (I. P. Martini, Department of Land Resource Science, Ontario Agricultural College, Univ. of Guelph, Guelph, Ontario N1G 2W1 Canada.)

April 30–May 2 10th Annual Rocky Mountain Groundwater Conference, Laramie, Wyo. (Peter Huntoon, Department of Geology, Univ. of Wyoming, Box 3006, Laramie, WY 82071.)

May 4–5 Seminar on Non-Sandstone Uranium Deposits, Golden, Colo. Sponsors, USGS, U.S. Department of Energy, Bendix Field Engineering Corp. (Geology Division, Bendix Field Engineering Corp., P.O. Box 1569, Grand Junction, CO 81502.)

May 4–8 **13th International Liège Colloquium on Ocean Hydrodynamics,** Liège, Belgium. Sponsors, IAPSO, Unesco Marine Sciences Division, EGS, Intergovernmental Oceanographic, AGU. (Jacques C. J. Nihoul, University of Liège, Mecanique des Fluides Géophysiques-Environment, B6- Sart Tilman, B-4000 Liège, Belgium.)

May 6–19 Annual Meeting, Mexican Geophysical Union, Manzanillo, Colima, Mexico. (Union Geofisica Mexicana, Comite Reunion 1981, Instituto de Geofisica, UNAM, Ciudad Universitaria, Mexico 20 D.F. Mexico.)

May 10–16 The Structure and Development of the Greenland-Scotland Ridge: New Methods and Concepts, Bressanone, Italy. Sponsor, NATO Advanced Research Institute. (Svend Saxov, Laboratory of Geophysics, Aarhus Univ., Finlandsgade 6-8, DK-8200 Aarhus N, Denmark.)

May 11–13 Annual Meeting, Canadian Geophysical Union, Calgary, Alberta, Canada. (P. J. Savage, Pan-Canadian Petroleum Ltd., P.O. Box 2850, Calgary, Alberta, Canada T2P 2S5.)

May 11–15 1981 Seminar on Tropical Cyclone Hydrology Miami, Fla. Sponsors, WMO, NOAA. (Allen F. Flanders, National Weather Service, 8060 13th St., Room 506, Silver Spring, MD 20910.)

May 13–20 IUCRM Symposium on Wave Dynamics and Radio Probing of the Ocean Surface, Miami, Fla. Sponsors, NOAA, NASA, ONR. (G. Valenzuela, Physical Oceanography Branch, Environmental Sciences Division, Code 4344, Naval Research Laboratory, Washington, DC 20375.)

May 14–15 27th Annual Meting of the Institute on Lake Superior Geology, East Lansing, Mich. Sponsor, Michigan State Univ. (F. W. Cambray, Department of Geology, Michigan State Univ., East Lansing, MI 48824.)

May 18–21 Rapid Excavation and Tunneling Conference, San Francisco, Calif. Sponsors, American Institute of Mining, Metallurgical, and Petroleum Engineers, American Society of Civil Engineers. (R. M. Oriogio, Assistant Conference Manager, Society of Mining Engineers, Caller No. D, Littleton, CO 80123.)

May 18–21 **The International Symposium on Rainfall-Runoff Modeling,** Mississippi State, Miss. (V. P. Singh, International Symposium on Rainfall-Runoff Modeling, Department of Civil Engineering, Mississippi State Univ., P.O. Drawer CE, Mississippi State, MS 39762.)

May 18–21 Proterozoic Symposium, Madison, Wis. Sponsor, Department of Geology and Geophysics, Univ. of Wisconsin-Madison. (L. G. Medaris, Jr., Department of Geology and Geophysics, Weeks Hall, Univ. of Wisconsin, Madison, WI 53706.)

May 25–29 **AGU Spring Meeting,** Baltimore, Md. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

May 25–29 International Tsunami Symposium 1981, Tsunami Commission of IUGG, Sendai-Ofunato, Japan. (E. Kajiura, Earthquake Research Institute, Univ. of Tokyo, Bunkyo-ku, Tokyo 113 Japan.)

May 27–29 Canadian Meteorological and Oceanographic Society 15th Annual Congress, Saskatoon, Saskatchewan, Canada. (B. E. Goodison, Program Chairman, Atmospheric Environment Service, 4905 Dufferin Street, Downsview, Ontario M3H 5T4 Canada.)

June 1–5 **Second International Symposium on Inertial Technology for Surveying and Geodesy,** Banff, Canada. Sponsors, AGU, Canadian Institute of Surveying, Univ. of Calgary. (Klaus-Peter Schwarz. ISS Symposium 1981, Division of Surveying Engineering, Univ. of Calgary, Calgary, Alberta T2N 1N4 Canada.)

June 3–4 Symposium on the Ecology and Management of Reservoirs, Université Laval, Quebec, Canada. Sponsors, Unesco, Université du Quebec, Université Laval, Hydro-Quebec, Société d'Energie de la Baie James. (P. G. C. Campbell, Université Quebec, INRS-Eau, C.P. 7500, Ste. Foy, Quebec G1V 4C7 Canada.)

June 4–5 Eastern Snow Conference. Syracuse, N.Y. (B. E. Goodison, Program Chairman, Atmospheric Environment Service, 4905 Dufferin Street, Downsview, Ontario M3H 5T4 Canada.)

June 7–11 **Eighth Ocean Energy Conference for the Department of Energy,** Washington, D.C. Sponsor, Marine Technology Society. (Harry Irwin, Marine Technology Society, 1730 M St., N.W., Washington, DC 20036.)

June 8–10 **International Geoscience and Remote Sensing Symposium,** Washington D.C. Sponsors, AGU, IEEE Geoscience and Remote Sensing Society. (F. T. Ulaby, Remote Sensing Laboratory, Univ. of Kansas Center for Research, Inc., West Campus, Lawrence, KS 66045.)

June 14–19 Second International Conference on Urban Storm Drainage, Urbana, Ill. Sponsors, Univ. of Illinois, International Liaison in Urban Storm Drainage, International Association of Hydraulic Research, International Association of Water Pollution Research, American Society of Civil Engineers. (B. C. Yen, Department of Civil Engineering, Univ. of Illinois, Urbana, IL 61801.)

June 15–19 International IEEE/APS Symposium, National Radio Science Meeting, and International IEEE/MTT Symposium, Los Angeles, Calif. (Prof. N. G. Alexopoulos, 7732 Boelter Hall, Department of Electrical Sciences, Univ. of California, Los Angeles, CA 90024.)

June 23–26 Seventh International Symposium on the Machine Processing of Remotely-Sensed Data, West Lafayette, Ind. Sponsor, Laboratory for Applications of Remote Sensing, Purdue Univ. (D. B. Morrison, Purdue Univ./LARS, 1220 Potter Dr., West Lafayette, IN 47906.)

June 24–26 International Symposium on Real-Time Operation of Hydrosystems, Waterloo, Ontario, Canada. Sponsor, Water Resources Group, Univ. of Waterloo. (T. E. Unny or E. A. McBean, Univ. of Waterloo, Department of Civil Engineering, Waterloo, Ontario N2L 3G1 Canada.)

July 5–11 Geocongress '81-South African Geodynamics Project and 3rd International Platinum Symposium, Pretoria, South Africa. Sponsors, Geological Society of South Africa, South African National Committee for the International Union of Geological Sciences, Society of Economic Geologists. (The Symposium Secretariat S. 217, CSIR, P.O. Box 395, Pretoria 0001 Republic of South Africa.)

July 8–10 National Conference on Environmental Engineering, Atlanta, Ga. Sponsor, Environmental Engineering Division of American Society of Civil Engineers. (F. Michael Saunders, 1981 National Conference on Environmental Engineering, School of Civil Engineers, Georgia Institute of Technology, Atlanta, GA 30332.)

July 15–17 Summer Computer Simulation Conference, Washington, D.C. Sponsors, Instrument Society of America, the Society for Computer Simulation. (William E. Buchanan, Applied Physics Laboratory, Johns Hopkins Road, Laurel, MD 20810.)

July 21–23 **Chapman Conference on Spatial Variability in Hydrologic Modeling,** Fort Collins, Colo. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

July 21–30 21st General Assembly of IASPEI, London, Ontario, Canada. (A. E. Beck, Department of Geophysics, Univ. of Western Ontario, London, Ontario N6A 5B7 Canada.)

July 27–30 **Eighth International Symposium on Urban Hydrology, Hydraulics, and Sediment Control,** Lexington, Ky. (Don J. Wood, Department of Civil Engineering, 206B Anderson Hall, Univ. of Kentucky, Lexington, KY 40506.)

Aug. 3–15 IAGA Fourth Scientific Assembly, Edinburgh, United Kingdom. (B. R. Leaton, Institute of Geological Sciences, Edinburgh EH9 3LA United Kingdom.)

Aug. 4–7 International Conference on Energy Education, Providence, R.I. (Donald Kirwan, Conference Chairman, Office of Energy Education, Univ. of Rhode Island, Kingston, RI 02881.)

Aug. 9–15 Symposium on Variations in the Global Water Budget, Oxford, United Kingdom. Sponsors, ICCL, IAHS, INQUA. (Prof. R. E. Newell, Department of Meteorology, 54-1520, MIT, Cambridge, MA 02139.)

Aug. 10–14 International Conference on Basement Tectonics, Oslo, Norway. Sponsor, Norwegian Petroleum Society. (Roy H. Gabrielsen, Department of Geology, Univ. of Oslo, P.O. Box 1047, Blindern, Oslo 3 Norway; or Don L. Baars, Department of Geology, Fort Lewis College, Durango, CO 81301.)

Aug. 10–14 Water Forum '81: Technical State of the Art Exchange, San Francisco, Calif. Sponsors, American Society of Civil Engineers, Irrigation and Drainage Division, Committee on Drainage. (P. M. Meyers, 509 North Roosevelt Blvd., Apt. D-105, Falls Church, VA 22044.)

Aug. 10–18 20th General Assembly of the International Union of Radio Science, Washington, D.C. (R. Y. Dow, National Academy of Sciences, 2101 Constitution Ave., Washington, DC 20418.)

Aug. 17–28 Third Scientific Assembly of IAMAP with Extraordinary General Assembly, Hamburg, Federal Republic of Germany. (S. Ruttenburg, NCAR, P.O. Box 3000, Boulder, CO 80307.)

Aug. 17–18 Open Symposium on Mathematical Models of Radio Propagation, Washington, D.C. Sponsor, URSI. (J. R. Wait, Bldg. 20, Electrical Engineering De-

partment, Univ. of Arizona, Tucson, AZ 85721.)

Aug. 17–22 Ninth International Symposium on Earth Tides, New York, N.Y. Sponsor, Columbia Univ. (J. T. Kuo, Aldridge Laboratory of Applied Geophysics, Henry Krumb School of Mines, Columbia Univ., New York, NY 10027.)

Aug. 18–21 Second Biennial Conference and Exhibition of the Australian Society of Exploration Geophysicists, Adelaide, South Australia. (J. Haigh, Conference Chairman, P.O. Box 42, Unley, South Australia 5061.)

Aug. 24–26 International Symposium on Management of Geodetic Data, Copenhagen, Denmark. Sponsors, IAG, the Danish National Committee of IUGG, Geodaetisk Institut. (C. C. Tscherning, International Symposium Management of Geodetic Data, Geodaetisk Institut, Gamlehave Alle 22, Charlottenlund DK-2920 Denmark.)

Aug. 24–29 Eighth Annual Meeting of the European Geophysical Society, Uppsala, Sweden. (C.-E. Lund, Chairman Local Organizing Committee, Institute of Solid Earth Physics, Uppsala University, Box 556, 22 Uppsala, Sweden.)

Aug. 28–Sept. 9 Arc Volcanism Symposium, Tokyo, Japan. Sponsors, Volcanological Society of Japan, IAVCEI. (Daisuke Shimozuru, IAVCEI Symposium on Arc Volcanism, Earthquake Research Institute, Univ. of Tokyo, Bunkyo-ku, Tokyo 113 Japan.)

Aug. 31–Sept. 5 Symposium on Geodetic Networks and Computations, Munich, West Germany. Sponsor, IAG. (Deutsche Geodätische Kommission, Bayerischen Akademie der Wissenschaften, Marstallplatz 8, D-8000 Munchen 22.)

Sept. United Nations Symposium on Water Management in Industrialized Areas, Lisbon, Portugal. (Chairman of the Executive Committee, International Symposium on Water Management in Industrial Areas, Portuguese Water Resources Association, c/o LNEC, Av. do Brasil, 101, 1799 Lisbon, Portugal.)

Sept. 7–12 Third International Symposium on Antarctic Glaciology, Columbus, Ohio. Sponsors, International Commission on Snow and Ice, International Glaciological Society. (Institute of Polar Studies, Ohio State Univ., 125 S. Oval Mall, Columbus, OH 43210.)

Sept. 13–17 National Water Well Association 33rd Annual Convention and Groundwater Technology Education Session, Kansas City, Mo. (NWWA, 500 West Wilson Bridge Rd., Worthington, OH 43085.)

Sept 16–18 **Oceans '81,** Boston, Mass. Sponsors, Marine Technology Society, IEEE Council of Oceanic Engineering. (R. Nagle, Publicity Manager, Raytheon Company, 141 Spring St., Lexington, MA 02173.)

Sept 17–18 **Midwest Meeting,** Minneapolis, Minn. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

Sept 17–18 **Pacific Northwest Regional Meeting,** Ellensburg, Wash. (Bob Bentley, PNAGU, Central Washington University, P.O. Box 1000, Department of Geology, Ellensburg, WA 98920.)

Sept. 20–22 National Water Well Association 34th Annual Convention and Exposition, Atlanta, Ga. (NWWA, 500 West Wilson Bridge Rd., Worthington, OH 43085.)

Oct. 6–8 International Conference on Time Series Methods in Hydrosciences, Burlington, Ontario. Sponsors, National Water Research Institute of the Canada Centre for Inland Waters and Water-Resources Branch of Ontario's Ministry of Environment. (A. El-Shaarawi, Aquatic Physics and Systems Division, NWRI, Canada Centre for Inland Waters, P.O. Box 5050, Burlington, Ontario L7R 4A6 Canada.)

Oct. 11–15 51st Annual International Meeting of the Society of Exploration Geophysicists, Los Angeles, Calif. (William L. Baker, Technical Program Chairman, c/o Chevron Oil Field Research Co., Box 446, La Habra, CA 90631.)

Oct. 13–16 Division of Planetary Sciences of the American Astronomical Society Annual Meeting, Pittsburgh, Pa. (B. Hapke, Dept. of Geology and Planetary Science, 321 Old Engineering Hall, University of Pittsburgh, Pittsburgh, PA 15260.)

Oct. 14–16 Third Surveying and Mapping Colloquium for the Petroleum Industry, Banff, Alberta, Canada. Sponsor, Canadian Petroleum Association. (Liz Hampton, Canadian Petroleum Association, 1500, 633 Sixth Ave., S.W., Calgary, Alberta, Canada T2P 2Y5.)

Oct. 26–30 Symposium on Quaternary Land-Sea Migration Bridges and Human Occupation of Submerged Coastlines, La Jolla, Calif. Sponsors, Quaternary Shorelines Commission of the International Union for Quaternary Research, Scientific Committee of the World Confederation of Underwater Activities. (Patricia M. Masters, Scripps Institution of Oceanography, A-012, La Jolla, CA 92093.)

Nov. 2–6 International Conference on the Venus Experiment, San Francisco Bay Area, Calif. Sponsor, NASA. (Dr. Lawrence Colin, Ames Research Center, Moffett Field, CA 94035.)

Nov. 30–Dec. 11 43rd Session of the International Statistical Institute, Buenos Aires, Argentina. (Jim R. Wallis, IBM, Research Division, Box 218, Yorktown Heights, NY 10598; or G. S. Watson, Bernoulli Society for Mathematical Statistics and Probability, Department of Statistics, Princeton Univ., Princeton, NJ 08544.)

Dec. 7–11 **AGU Fall Meeting,** San Francisco, Calif. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

Dec. 18–19 Annual International Meeting of the Working Group on Mediterranean Ophiolites, Florence, Italy. (Luigi Beccaluva, Istituto di Petrografia, Via Gramsci 9, 43100 Parma, Italy.)

1982

Feb. 8–12 **Third International Geodetic Symposium on Satellite Doppler Positioning,** Las Cruces, N. Mex. Sponsors, Defense Mapping Agency, National Ocean Survey, AGU. (Richard Peat, Defense Mapping Agency, Hydrographic/Topographic Center, 6500 Brooks Lane, N.W., Washington, DC 20315.)

Feb. 16–19 **AGU Oceanography Section/ASLO (American Society of Limnologists and Oceanographers) Meeting,** San Antonio, Tex. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

April 19–21 Cordilleran Section, Geological Society of America and Seismological Society of America Annual Meeting, Anaheim, Calif. (Neil Maloney, Earth Science Department, California State Univ., Fullerton, CA 92634.)

May 3–7 **14th International Liège Colloquium on Ocean Hydrodynamics,** Liège, Belgium. Sponsors IAPSO, Unesco Marine Sciences Division, EGS, Intergovernmental Oceanographic, AGU. (Jacques C. J. Nihoul, University of Liège, Mecànique des Fluides Géophysiques-Environment, B6- Sart Tilman, B-4000 Liège, Belgium.)

May 7–20 General Meeting of IAG, Tokyo, Japan. (I. Nakagawa, Geophysical Institute, Kyoto University, Sakyo-ku, Kyoto 606 Japan.)

May 10–15 General Meeting of IAG, Tokyo, Japan. (M. Louis, IAG, 39 Rue Gay Lussac, 75005 Paris, France.)

May 24–June 4 International Solar-Terrestrial Physics Symposium, Ottawa, Ontario, Canada. (Professor Liu, University of Illinois, Urbana, IL 61801.)

May 24–June 4 24th Plenary Meeting of COSPAR Ottawa, Ontario, Canada. (Dean Kastel, Space Sciences Board, National Academy of Sciences, 2101 Constitution Ave., N.W., Washington DC 20418.)

May 31–June 4 **AGU Spring Meeting,** Philadelphia, Pa. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

June 27–July 2 Fifth International Conference on Geochronology, Cosmochronology, and Isotope Geology, Nikko National Park, Japan. (K. Shibata, Geological Survey of Japan, Higashi 1-1-3, Yatabe, Ibaraki 305 Japan.)

July 19–30 Scientific Meeting of IAHS with Extraordinary General Assembly, Exeter, United Kingdom. (John C. Rodda, Department of the Environment, Water Data Unit, Reading Bridge House, Reading RG1 8PS United Kingdom.)

Aug. 2–13 Joint Oceanographic Assembly, Halifax, Nova Scotia, Canada. Sponsor, Scientific Committee on Oceanic Research. (Leo O'Quinn, National Steering Committee for JOA, c/o Canadian Committee on Oceanography, 240 Sparks St., Ottawa, Ontario K1A 0E6 Canada.)

Aug. 15–21 Fourth International Symposium on Antarctic Earth Sciences, Ingle Farm, South Australia, Australia. Sponsors, Australian Academy of Science, Australian Academy of Technological Sciences, International Union of Geological Sciences, Scientific Committee on Antarctic Research, Geological Society of Australia, Inc., Univ. of Adelaide. (J. B. Jago, South Australian Institute of Technology, P.O. Box 1, Ingle Farm, South Australia, Australia 5098.)

Aug. 15–22 International Meeting on Generation of Major Basalt Types, Reykjavik, Iceland. Sponsors, IAVCEI, IAGC. (Basalt Meeting, c/o G. E. Sigvaldason, Nordic Volcanological Institute, 101 Reykjavik, Iceland.)

Aug. 15–22 IAVCEI and IAGC Joint Meeting, Reykjavik, Iceland. (G. E. Sigvaldason, Nordic Volcanological Institute, Univ. of Iceland, Geosciences Building, 101 Reykjavik, Iceland.)

Aug. 22–28 11th International Congress on Sedimentology, Hamilton, Ontario, Canada. Sponsor, IAS. (IAS Congress 1982, Department of Geology, McMaster University, Hamilton, Ontario L8S 4M1, Canada.)

Aug. 23–27 Ninth Annual Meeting of the European Geophysical Society, Leeds, United Kingdom. (C. R. Argent, EGS Secretary, The Royal Society, 6 Carlton House Terrace, London SWIY, 5AG, England.)

Sept. Third International Kimberlite Conference, Clermont-Ferrand, France. (Francoise Boudier, Université de Nantes, Laboratoire de Tectonophysique, 2 Rue de la Houssiniere, 44072 Nantes, France.)

May or Sept. Scientific Meeting of IAPSO, Halifax, Canada. (E. C. LaFond, LaFond Oceanic Consultants, P.O. Box 7325, San Diego, CA 92017.)

Dec. 6–10 **AGU Fall Meeting,** San Francisco, Calif. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

1983

July 18–23 Fourth International Conference on Permafrost, Fairbanks, Alaska. Sponsors, National Academy of Sciences, State of Alaska. (L. De Goes, Polar Research Board, National Academy of Sciences, 2101 Constitution Ave., N.W., Washington, DC 20418.)

Aug. 15–26 18th General Assembly of IUGG, Hamburg, Federal Republic of Germany. (P. Melchior, Observatoire Royal de Belgique, Avenue Circulaire 3, B-1180 Bruxelles, Belgium.)

Aug. 27 Symposium Commemorating the 100th Anniversary of the Mount Krakatau Eruption, Jakarta, Indonesia. Sponsor, Indonesian Institute of Sciences. (Didin Sastrapradja, Deputy Chairman for Natural Sciences, L1P1 JL, Teuku Chik Ditiro 43, Jakarta, Indonesia.)

Sept. 12–14 National Water Well Association 35th Annual Convention and Exposition, St. Louis, Mo. (NWWA, 500 West Wilson Bridge Rd., Worthington, OH 43085.)

Dec. 5–9 **AGU Fall Meeting,** San Francisco, Calif. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

FUTURE AGU MEETINGS

Fall Meetings
December 7–11, 1981, San Francisco
December 6–10, 1982, San Francisco
December 5–9, 1983, San Francisco

Spring Meetings
May 25–29, 1981, Baltimore
May 31–June 4, 1982, Philadelphia

AAPG American Association of Petroleum Geologists
AMS American Meteorological Society
ASCE American Society of Chemical Engineers
GSA Geological Society of America
IAG International Association of Geodesy
IAGA International Association of Geomagnetism and Aeronomy
IAHS International Association for Hydrological Sciences
IAMAP International Association of Meteorology and Atmospheric Physics
IAPSO International Association of Physical Sciences of the Ocean
IASPEI International Association of Seismology and Physics of the Earth's Interior
IAVCEI International Association of Volcanology and Chemistry of the Earth's Interior
IUGS International Union of Geological Sciences
IWRA International Water Resources Association
MSA Mineralogical Society of America
SEG Society of Exploration Geophysicists
SEPM Society of Economic Paleontologists and Mineralogists
URSI International Union of Radio Science

GAP

Hydrology

[illegible]

3130 Groundwater
AQUIFER PARAMETER IDENTIFICATION WITH OPTIMUM DIMENSION IN PARAMETERIZATION
W. W-G. Yeh (University of California, Los Angeles, California 90024) and Y. S. Yoon (Boyle Engineering Corporation, San Diego, California 92111)
This paper presents a systematic procedure whereby the functional coefficients imbedded in a two-dimensional partial differential equation that governs an unsteady groundwater flow are optimally identified. The coefficients to be identified are transmissivities which vary spatially. Finite elements are used to represent the unknown transmissivity function parametrically in terms of nodal values over a suitable discretization of a flow region. A modified Gauss-Newton algorithm is used for parameter optimization. Covariance analysis is used to estimate the reliability of the estimated parameters. As the dimension of the unknown parameter increases, the modeling error represented by a least-squares criterion will generally decrease, but errors in data would be propagated to a greater degree into the estimated parameters, thus reducing the reliability of estimation. The reliability of the estimated parameters is characterized by a norm of the covariance matrix. This information is used for the determination of the optimum dimension in parameterization. (Parameter identification, Inverse problem, Optimization, Covariance analysis).
Water Resour. Res., Paper 1W0084

3170 Snow and ice
SNOW SURFACE ENERGY EXCHANGE
D. Male (Division of Hydrology, University of Saskatchewan, Saskatoon, Saskatchewan, Canada, S7N 0W0) and B. Granger
The radiation transfer and the turbulent exchange processes at a snow surface are reviewed. It is shown that significant advances in the simulation of the radiation budget have been made in the last few years particularly in the calculation of albedo. In addition a variety of techniques of varying complexity have been developed to model the exchange process in the presence of clouds or a forest cover.
The simulation of the turbulent exchange process is not as advanced as that of the radiation exchange. Methods of relating point measurements of the latent and sensible heat exchange to large areas based on changes in elevation, latitude, state of the air mass or topographical characteristics are non-existent. It is suggested that investigations of large-scale or air-mass influences on the turbulent energy exchange will likely yield practical results in a relatively short period of time.
Water Resour. Res., Paper 8OW1501

3190 General or miscellaneous
RELIABILITY PROGRAMING IN RESERVOIR MANAGEMENT 2. RISK-LOSS FUNCTIONS
Slobodan P. Simonovic (Department of Land, Air and Water Resources and Department of Civil Engineering, University of California, Davis, California 95616) and Miguel A. Marino
The reliability programing approach for reservoir management is based on the concept of risk-loss functions. This paper presents a methodology for deriving the risk-loss functions associated with the violations of a freeboard constraint (flood risk) and a water-supply storage constraint (drought risk). A relation between the amount of water excess or shortage and its corresponding reliability level is first established. The excesses or shortages are then related to damages (losses). This provides the basis for a final relation of the reliability levels and the damages (losses). A similar approach can be followed in developing the risk-loss functions associated with other reservoir purposes, such as recreation, navigation, and water-quality enhancement. The hydrologic, hydraulic, and economic data necessary for developing the risk-loss functions are discussed. The methodology is illustrated using data from the Blue Marsh reservoir on Tulpehocken Creek, Schuylkill River Basin, Pennsylvania.
Water Resour. Res., Paper 1W0148

Meteorology

3720 Climatology
LONG-TERM MEANS AND SHORT-TERM VARIABILITY OF THE SURFACE ENERGY BALANCE COMPONENTS AT THE SOUTH POLE
J. J. Carroll (Department of Land, Air and Water Resources, University of California, Davis CA 95616, U.S.A.) and B. W. Fitch.
Based on a nearly continuous data set obtained between April 1975 and December 1977, a summary of seasonal means of the directly measured and calculated energy fluxes and examples of the short-term (daily) variability in these components in response to changing synoptic conditions are presented. The seasonally averaged observations are consistent with those of previous studies, indicating that throughout most of the year a net radiative loss from the surface occurs averaging 11 to 13 Wm^{-2} per year. In summer, the downward flux of heat from the air (Hs) exceeds the net radiation losses by 10 to 20%, resulting in storage of heat in the deep snowpack. In winter the radiative losses average between 16 and 20 Wm^{-2} with Hs supplying 85 to 90% of this loss and the remaining 10 to 15% supplied from deep storage in the snow.
On daily time scales, the energy balance components are highly variable, with ranges several times their long term means. This variability appears to result from variation in forcing associated with variations in the large scale flow -- namely: changing large scale pressure gradient, cloudiness and variations in the mean temperature of the lower atmosphere (i.e., z ≤ 1 km).
J. Geophys. Res., Green, Paper 1C0263

3740 General circulation
PLANETARY WAVES AND SOLAR ACTIVITY IN THE STRATOSPHERE BETWEEN 50 AND 10 MBAR
A. Ebel (Institut fuer Geophysik und Meteorologie der Universitaet zu Koeln, 5000 Koeln 41, F.R.G.) B. Schwister and K. Labitzke
The effects of solar activity on the geopotential height and temperature fields of the 50-, 30-, and 10-mbar surface, resolved into harmonic components, were investigated. This was done by means of cross spectral analysis between the 10.7-cm radiation of the sun and planetary waves up to zonal wave number three. Frequent significant responses of various harmonic components in a broad range of oscillation frequencies give evidence that solar activity plays a significant role for the dynamics of the middle and lower stratosphere. Oscillations of the zonal harmonics which are coherent with solar activity fluctuations were extracted from the spectra and recomposed into coherent (planetary) waves. Three waves with periods of 25 days (near to the sun's rotation period), 13.6 d (first harmonic of solar rotation), and 15.1 days (corresponding to the well-known 15 - 16-day wave in the atmosphere are examined in detail. They show the properties of free planetary modes (13.6 d and 15.1 d) and possibly of internal waves (25 d) at higher latitudes. Vacillation cycles of the mean atmospheric state (including stationary waves) seem to be important for the generation of the studied wave phenomena.
J. Geophys. Res., Green, Paper 1C0273

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3750 General circulation
SEASONAL VARIATIONS IN GLOBAL SEA LEVEL PRESSURE AND THE TOTAL MASS OF THE ATMOSPHERE
Kevin E. Trenberth (Laboratory for Atmospheric Research, University of Illinois, Urbana, IL 61801)
The annual cycles of sea level and surface pressures and the atmospheric pressure due to water vapor have been analyzed in detail. Global sea level pressures undergo an annual cycle of 6.5 mb range with a maximum in the northern winter. Global surface pressures, which represent the total mass of the atmosphere, also undergo an annual cycle of 0.5 mb range but with the maximum in the southern winter. The changes in water vapor concentrations are responsible for the latter—water vapor has a maximum in the southern winter. The constancy of the mass of dry air is used as a check on the accuracy of computations. The total mass of the atmosphere is 513.7 × 10^{16} kg with a standard error of .02 × 10^{16} kg. The corresponding global mean surface pressure of the atmosphere is 984.68 mb. The mean total mass of water vapor is 1.3 × 10^{16} kg which corresponds to [illegible] of water [illegible]. The distribution of pressure and mass as a function of latitude are also presented. [illegible] sea level pressure undergo [illegible] the sea level [illegible] annual cycle [illegible] of this, 54% [illegible] hemisphere and [illegible] ficial atmosp[illegible] relative to [illegible] cycles, water vapor).
J. Geophys. Res., Green, Paper 1C0277

3743 General circulation
LINEAR AND NONLINEAR ASPECTS OF SNOW ALBEDO FEEDBACKS IN ATMOSPHERIC MODELS
John O. Roads (Scripps Institution of Oceanography, La Jolla, California 92093)
[illegible]
J. Geophys. Res., Green, Paper 1C0275

3770 Particles and aerosols
THE MARTIAN TWILIGHT
Ralph Kahn (Dept. of Astronomy, Cornell University, Ithaca, [illegible]) Richard Goody and James Pollack
The changing sky brightness during the martian twilight as [illegible] has been compared with [illegible] models of [illegible] sphere. [illegible]
J. Geophys. Res., [illegible]

Mineralogy, Petrology, and Crystal Chemistry

4260 MELT SEGREGATION FROM PARTIALLY MOLTEN SOURCE REGIONS: THE IMPORTANCE OF MELT DENSITY AND SOURCE REGION SIZE
E. Stolper (Div. Geol. Planet. Sci., Caltech, Pasadena, CA 91125) D. Walker, B.H. Hager and J.F. Hays
The compressibility of basic melt at 1 atmosphere is about an order of magnitude higher than that of mantle minerals. Consequently, the density contrast between melt and the principal residual crystals in mantle source regions is expected to decrease with increasing source region depth. The increasingly olivine-normative character of primary melts produced at greater depths is also expected to result in a decrease in this density contrast with increasing source region depth.
Once vertical permeability is established by melt generated during partial melting, buoyancy-driven melt percolation can under some circumstances segregate melt from the residual crystals in its source region on a geologically rapid time scale. Limits to this process are provided by cooling of the source region (freezing melt in) and rigidity of the crystalline matrix (mechanically trapping melt). Source region size influences these limits strongly: consequently, small, partially molten diapirs (~km in diameter) may be able to trap large melt fractions (≳30%), but larger source regions would be unable to do so. The reduction in density contrast with pressure reduces the buoyant force driving melt percolation and provides another limit to melt segregation. Diapirs at depth may thus stably contain large fractions of melt but may decompress and unload their melt during ascent; this effect would be enhanced in small diapirs and may be relevant to the genesis of komatiitic magma. Melt compression may also be a factor in explaining why the very different maximum depths inferred for typical basic melt segregation from source regions on different planets — ~500 km on the moon, ~250 km on Mars, ~100 km on earth — correspond to similar pressures (25–35 kbar); at greater pressures, melt may no longer be capable under ordinary conditions of segregating upwards by buoyancy. This may also help to explain why depleted peridotites overlie more fertile peridotites and how deep regions of the mantle are able to remain fertile over geologic time. (diapirs, igneous petrology, komatiites, melt migration)
J. Geophys. Res., Red, Paper 1B0210

4260 Paragenesis, petrography and petrogenesis
BASEMENT DRILLING IN THE WESTERN ATLANTIC OCEAN: I. MAGMA FRACTIONATION AND ITS RELATION TO ERUPTIVE CHRONOLOGY
H. F. J. Flower (Dept. of Geol. Sci., Univ. of Illinois, Chicago, IL 60680) P. T. Robinson
Petrologic/geochemical studies of basalts drilled in Cretaceous oceanic crust (DSDP Legs 51-53) in the Western Atlantic Ocean are synthesized in quantitative models of magma fractionation mechanisms. From least-squares analysis of whole-rock, glass and phenocryst phase compositions it is concluded that fractionation by crystallization of olivine, plagioclase and clinopyroxene involved gravitative separation of mafic phases from plagioclase. Flotation of plagioclase together with disequilibrium reaction morphologies suggest crystallization began shortly after generation of primitive liquids in the mantle. Polybaric fractionation and mixing of derivative magma batches are indicated by evidence for solid-liquid reaction and low-pressure re-equilibration. Eruptive 'series' bounded by magnetic and other stratigraphic discontinuities correspond to chemically-defined magma fractionation series. The latter probably derive from distinct parental magma batches distinguished from one another through small differences in degree of partial melting. Lithophile element character reflects homogeneous 'depleted' source material persisting during crustal construction at the Atlantic ridge axis. The whole-rock and glass selvedge compositional averages for eruptive units reflect the importance of post-eruptive phenocryst redistribution and syn-eruptive changes in liquid fraction compositions. (magma, fractionation, petrogenesis, ocean crust, lava)
J. Geophys. Res., Red, Paper 1B0261

Oceanography

4713 Circulation
SUBTIDAL FLUCTUATIONS OFF THE NATAL COAST
E.H. Schumann (National Research Institute for Oceanology, P.O.Box 17001, Congella 4013, South Africa)
Conditions on the continental shelf off the Natal coast are described in terms of the effect on fluctuations in currents, temperature and (to a limited extent) sea level. The results of measurements made at four mooring points along the coast are then analysed for fluctuations in the 2 to 20 day period range. The longshore wind component is shown to play a major role in the circulation dynamics, however the effect of topographic variations and the associated flow of the Agulhas Current also serve to produce markedly differing regimes. Thus in the northern region it is found that the currents are almost entirely wind-dominated, while further south non-local signals propagating into the regions produce a diffent form of response. The measurements are not comprehensive enough to allow more detailed investigations as to the nature of these signals. (Continental shelf, currents, temperature, wind generation).
J. Geophys. Res., Green, Paper 1C0122

4720 Distributions and water masses
A NOTE ON SOME USES OF θ-S SECTIONS
J.G. Bruce (Woods Hole Oceanographic Institution, Woods Hole, MA 02543)
Isohalines plotted against temperature and horizontal distance along a hydrographic section can be used to observe changes in the T-S or θ-S relationship of water masses. Using this technique eddies formed off the Somali coast during the southwest monsoon or Gulf Stream eddies having their own individual T-S characteristics may be identified.
J. Geophys. Res., Green, Paper 1C0224

4725 Estuaries, Bays and Fjords
OBSERVATIONS OF SURFACE AND BOTTOM DRIFTER MOVEMENTS IN THE BEAUFORT SEA NEAR PRUDHOE BAY, ALASKA
J. B. Matthews, (Geophysical Institute, University of Alaska, Fairbanks, Alaska 99701)
Surface drifters have been released in the Beaufort Sea near Prudhoe Bay for three consecutive years. Two releases were made after the shorefast ice had broken up and one release was made just prior to breakup. All drifter recoveries suggest that the movements result from prevailing wind-driven currents during the open water season although there are small currents under the ice in winter which probably contribute to the observed movements. Drifters released just before a large storm travelled the greatest distances (536 km) in the shortest time (40 days) with mean velocities close to 10 cm/sec. These travel times and computed speeds are consistent with the values of 3% of the wind transport over the same period. The statistics of drifter recoveries are comparable to those for coastal regions in North America despite the very sparse population along the arctic coast. For the under-ice releases, there was a consistent shorewards movement even for drifters released as far as 10 km offshore, indicated by the recovery data. This result suggests that oil released under ice in winter would tend to move shorewards. Subsequently oil patches would be wind-driven after spring breakup of the land-fast ice. (Surface currents, currents under ice, bottom currents, Arctic Ocean)

4740 Marine geological processes
DYNAMICS AND GEOMETRY OF WAVE GENERATED RIPPLES
P. Nielsen (Coastal Studies Unit, Department of Geography, University of Sydney, 2006, N.S.W., Australia)
Semi empirical formulae for the size and shape of sand ripples are derived from an analysis of the water and sediment motion over a rippled bed in oscillatory flow. Simple physical arguments show that ripple steepness should be a function of the non dimensional shear stress θ' and the angle of repose of the bed material. All available data seem to support this. The mechanisms that determine the ripple length are very complex, and at least four non dimensional parameters are important. However, for practical purposes the ripple length is well determined by the mobility number ψ. ψ is essentially the ratio of the water velocity amplitude to the sediment settling velocity. Both ripple length and ripple height are shown to depend mainly on ψ, when only quartz sand and natural wave periods are considered. The derived formulae apply well to the full range of flow conditions, where ripples occur. Natural ripples obey essentially the same rules as laboratory ripples, however, they are generally shorter and flatter due to the irregularity of natural waves.
J. Geophys. Res., Green, Paper 1C0250

4760 Sea Ice
SEA ICE, WINTER CONVECTION AND THE TEMPERATURE MINIMUM LAYER IN THE SOUTHERN OCEAN
John M. Toole (Pacific Marine Environmental Laboratory, 3711 15th Ave. NE, Seattle, WA 98105)
The structure of the near surface waters in the Southern Ocean, poleward of the Antarctic Polar Front, is investigated with a three dimensional time dependent numerical model which resolves the annual sea ice cycle. The growth and decay of the ice field is predicted, using one of Semtner's (1976) thermodynamic ice models, in terms of specified atmospheric data and computed thermohaline characteristics of the ocean layers. The ice field is found to be sensitive to the lateral advection of heat by the oceanic circulation as well as vertical heat transports due to deep winter convection. The model treats the temperature minimum layer in the Southern Ocean as the remnant of a deep winter mixed layer which becomes capped by surface heating and precipitation in summer. The predicted thermohaline characteristics of the temperature minimum layer and the surface mixed layer are in good agreement with observations. Finally, the annual air-sea heat exchange predicted by the model is discussed. The model's predicted area averaged heat loss experienced by the ocean south of the Atlantic Polar Front is much smaller than previously estimated. This is attributed to errors in the southern region of the model domain. It is suggested that models, which include the interactions between sea ice and surface, deep and bottom waters along the continental margins are needed to investigate this region.
J. Geophys. Res., Green, Paper 1C0353

4765 Tides
TIDALLY-INDUCED "UPWELLING" BY THE GREAT BARRIER REEF
Rory O.R.Y. Thompson and T.J. Golding (CSIRO Division of Fisheries and Oceanography, P.O. Box 21, Cronulla, NSW 2230, Australia)
The Great Barrier Reef is similar to some other coral reefs in growing right up to the edge of the shelf in a region of nutrient-poor surface water, but large tides. It is suggested that the resultant strong tidal currents suck in nutrient-rich water from the nearby deep water. The nutrients could encourage the reef to grow vigorously at the edge of the shelf. Some observations in Cook's Passage (14°32'S, 145°31'E) were made to test the concept and are encouraging. (tidal suction, reef nutrients, upwelling)
J. Geophys. Res., Green, Paper 1C0357

4790 Instruments and techniques
THE FIRST DECADE OF GLORIA
A.S. Laughton (Institute of Oceanographic Sciences, Wormley, Godalming, Surrey, U.K.)
A geological long range side-scan sonar (GLORIA) [illegible] swath of ocean floor sixty km wide. In ten years of operation it has been used on 26 cruises and has insonified more than one per cent of the ocean floor. The paper reviews the scientific achievements of this tool and assesses the contributions which it has made to understanding geological features and the processes creating them. A complete bibliography of GLORIA related papers is given and the best examples of sonographs of the different terrains are illustrated.
J. Geophys. Res., Red, Paper 1B0297

4799 General or miscellaneous
DISTRIBUTION OF MICROBUBBLES IN COASTAL WATERS
P. L. Mulhearn (R.A.N. Research Laboratory, P.O. Box 706, Darlinghurst, 2010, Australia).
After a discussion of likely mechanisms for bubble generation in the ocean it is suggested that the observed bubbles are either due to decaying matter on the sea-floor, or that they are bubbles trapped by [illegible] processes on marine detritus. The latter persist for long periods, their [illegible] being inhibited by [illegible] to particles and their dissolution rate inhibited by surfactant contamination. The mathematical models constructed to investigate these hypotheses show good agreement with the data of Medwin (1970). (bubbles, coastal waters).
[illegible]

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5715 Magnetic tail
ENERGETIC PARTICLES IN THE PRE-DAWN MAGNETOTAIL OF JUPITER
A. Schardt (Laboratory for High Energy Astrophysics, NASA/Goddard Space Flight Center, Greenbelt, MD, USA) F. McDonald and J. Trainor
A detailed account is given of the energetic electron and proton populations as observed with Voyagers 1 and 2 during their passes through the dawn magnetotail of Jupiter. The region between 20 and 150 R_J is dominated by a thin plasma sheet, where trapped energetic electron and proton fluxes reach their maximum. Proton spectra can be represented by an exponential in rigidity with a characteristic energy of ~50 keV. Proton anisotropies were consistent with corotation even at 100 R_J. A major proton acceleration event as well as several cases of field-aligned proton streaming were observed. The flux of ~0.4 MeV protons decreases by three orders of magnitude between 30 and 90 R_J and then remains relatively constant to the magnetopause. Fine structure in the data indicate longitudinal asymmetries with respect to the dipole orientation. Electron spectra in the magnetosheath and interplanetary space are modulated by the Jovian longitude relative to the subsolar point.
J. Geophys. Res., Blue, Paper 8U1515

5739 Magnetopause
WAVE-PARTICLE INTERACTIONS AT THE MAGNETOPAUSE: CONTRIBUTIONS TO THE DAYSIDE AURORA
B. T. Tsurutani (Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91103), E. J. Smith, R. M. Thorne, R. R. Anderson, D. A. Gurnett, G. K. Parks, C. S. Lin and C. T. Russell
A strong correlation between intense, broad-band 10-10^3 Hz plasma waves and 1-6 keV electrons and protons are observed on ISEE 1 and 2 at the low latitude dayside magnetopause. Wave and particle features have been characterized by taking averages over ten events. The 10-10^3 Hz magnetic waves and the 10-10^5 Hz electric emissions can be represented by the power-law spectra, $I_B = 10^{-1.9}$ nT²/Hz and $I_E = 1 \times 10^{-5} f^{-2.8}$ V²/m² Hz, respectively. The electron and proton fluxes and spectral shapes are nearly constant from event-to event, and are characterized by $j = 3 \times 10^{?} E^{-1.8}$ cm^{-2}sec^{-1}ster^{-1}keV^{-1} and $j = 10^7 E^{-2.5}$ cm^{-2}sec^{-1}ster^{-1}keV^{-1}. Using typical magnetopause plasma and field values of 20 cm^{-3} and 50 nT, it is shown that the 1-10 keV electrons and protons are scattered near the limit of strong pitch angle diffusion by the observed waves. A precipitation flux of 0.15 ergs/cm²sec is calculated, indicating a significant contribution to the dayside aurora.
Geophys. Res. Lett., Paper 9?1575

5755 Plasma instabilities
SOLAR WIND PICKUP OF IONIZED VENUS EXOSPHERE ATOMS
R. A. Hartle (Laboratory for Planetary Atmospheres, Goddard Space Flight Center, Greenbelt, MD 20771)
Previous calculations of electrostatic and electromagnetic growth rates for plasma instabilities have neglected the thermal spread of the distribution function of the planetary ions. We consider the effects of finite temperatures for exospheric ions born in the solar wind. Specifically, growth rates are calculated for electromagnetic instabilities in the low frequency case for Alfven waves and the intermediate frequency case for whistlers. Also, electrostatic growth rates are calculated for the intermediate frequency region. From these growth rates, estimates are derived for the pickup times of the planetary ions. The electromagnetic instabilities are shown to produce the most rapid pickup. In the situation where the angle between the local Venus magnetic field and the plasma flow direction is small, the pickup times for both electromagnetic and electrostatic instabilities become very long. A possible consequence of this effect is to produce regions of enhanced planetary ion density in favorable Venus magnetic field-solar wind flow geometries.
J. Geophys. Res., Blue, Paper 1A0220

5755 Plasma instabilities
STABILITY THEORY OF DRIFT-LIKE ELECTROMAGNETIC WAVES IN TWO DIMENSIONAL MAGNETIC FIELDS
S. Migliuolo (Physics Department, University of Denver, Denver, Colorado 80208), V. L. Patel
A two component (hot and cold) magnetospheric plasma, with spatially varying densities and temperatures, is considered for the case where the equilibrium magnetic field is two-dimensional. A slab geometry includes the effect of field line bending to first order. A linear theory of low frequency, long wavelength, electromagnetic modes is developed. The modes are driven unstable by the spatial gradients in density, temperature, and B-field. The electrons of the cold component determine the polarization of the wave (in the meridional plane). A flute-like instability of the drift-compressional mode is found to occur. We find the critical value of the field curvature scale length, below which this mode is stable. Analytic expressions for the eigenfrequency and eigenvectors are given. The perturbed fields are found to be strongly localized in the radial direction.
J. Geophys. Res., Blue, Paper 1A0??1

5755 Plasma instabilities
THE RELATIONSHIP OF FIELD-ALIGNED CURRENTS TO ELECTROSTATIC ION CYCLOTRON WAVES
Cynthia Cattell (Space Sciences Laboratory, University of California, Berkeley, California 94720)
Two sources of free energy for driving ion cyclotron waves have been observed on the S3-3 satellite - field-aligned currents and ion beams. Since the waves are destabilized by the thermal electron drift and not the current, before correlating observations of field-aligned currents with ion cyclotron waves, it is first necessary to determine that the current is primarily carried by thermal electrons. Comparisons of the current carried by energetic particles with the current measured by the magnetometer during several events shows that this is sometimes the case. Statistical studies indicate that the field-aligned current density is correlated with the spectral density during ion cyclotron events. The combination of the results of this report and those of *Kintner et al.* [1979] is consistent with the hypothesis that the observed ion cyclotron waves are driven by a combination of ion beams and electron drift. However, the available data set does not unambiguously identify the free energy source.
J. Geophys. Res., Blue, Paper 1A0191

5760 Plasma motion, convection, or circulation
EVIDENCE FOR THE TAILWARD RETREAT OF A MAGNETIC NEUTRAL LINE IN THE MAGNETOTAIL DURING SUBSTORM RECOVERY
T. G. Forbes, E. W. Hones (University of California, Los Alamos National Laboratory, Los Alamos, NM 87545) S. J. Bame, J. R. Asbridge, G. Paschmann, N. Sckopke, and C. T. Russell
On several occasions during the recovery phase of substorms the Los Alamos/MPI analyzers on the ISEE 1 and 2 satellites have observed protons counter-streaming along the magnetic field within about 1 R_E of the northern (upper) surface of the plasma sheet. We present data for one of these periods (04:00-04:30, March 1, 1978) which strongly suggest that the counter-streaming of the protons results from the mirroring of particles moving Earthward along the magnetic field. Only the Earthward flow is observed when the satellites first encounter the plasma sheet. But about 2 minutes after the entry into the plasma sheet the return tailward flow appears while the Earthward flow continues. The speeds of both the Earthward and tailward moving populations thereafter show a systematic decrease with time with the tailward speed being persistently ~200 km/sec greater than the Earthward speed. Analysis of the correlation between the speeds of the two populations shows that the decrease in speed results from the relative motion of the satellites with respect to a spatial gradient in the velocity at the boundary of the plasma sheet. We interpret the time delay between the onset of the Earthward and tailward streaming protons and the persistent difference between their speeds as evidence that the source of the Earthward flow is moving tailwards onto magnetic field lines mapping to progressively higher polar latitudes as substorm recovery proceeds and we suggest that the source is the region of magnetic reconnection associated with a tailward retreating neutral line. (Plasma flow, neutral line, substorm).
Geophys. Res. Lett., Paper 1L0171

5775 Trapped particles
COMPOSITION OF NON-THERMAL IONS IN THE JOVIAN MAGNETOSPHERE
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We present observations from Voyager 1 and 2 of non-thermal ions from H through Fe in the Jovian magnetosphere using the Low Energy Particle Telescope (LEPT), one of the two sensors of the Low Energy Charged Particle (LECP) experiment. At ~1 MeV/nuc, the major constituents of the ion population were H, He, C, O, Na, S and the hydrogen molecules H_2 and H_3. Relative to He, the abundance of H and H_2 at equal energy/nucleon was highest in the outer magnetosphere, the abundance of O, Na, and S was highest in the inner magnetosphere, and the abundance of C was constant throughout the magnetosphere. He and C may be of largely solar origin while H_2, H_3, O, Na, S are largely of local origin. The variations in abundance ratios were accompanied by a general hardening of the energetic particle spectra near 1 MeV/nuc with decreasing radial distance. We are able to find a parameter n, assumed to be a species-dependent constant times energy/nucleon, in terms of which the flux ratios among most species do not change with radial distance. These "invariant" ratios indicate that there are approximately equal numbers of non-thermal O, S, and He ions, with the abundance of H ions being a factor of ~15 higher. The large ratio changes at equal energy/nucleon can then be ascribed to the changing spectral slopes. The parameter n may be reasonably identified with energy/charge, in which case we are able to deduce relative charge to mass ratios for H, He, C, O and S. If He is doubly ionized, we find that the non-thermal carbon has an approximate charge state of +6, typical of solar wind particles, while oxygen and sulfur have low charge states (+2 to +4), typical of local plasma sources. Spectral changes over the range of ~30 R_J to ~16 R_J, in this interpretation, are consistent with particle energization by inward radial diffusion conserving the first adiabatic invariant. In the Jovian magnetotail, at the time of the Voyager 2 outbound pass, the energetic particle population was a combination of Jovian particles with soft spectra and interplanetary particles (probably of solar flare origin) with much harder spectra. Above ~1 MeV/nuc, the interplanetary particles were dominant. Beyond ~160 R_J, in the "magnetospheric wind" region, the non-thermal ion intensity increased and reflected an oxygen- and sulfur-rich composition typical of the middle magnetosphere. Two short-lived intensity increases were observed at ~190 R_J which had heavy ion abundance ratios and spectra similar to those found in the inner magnetosphere. The release of these particles was apparently associated with the arrival at Jupiter of a fast solar wind stream.
J. Geophys. Res., Blue, Paper 1A0255

5775 Trapped Particles
ION COMPOSITION OF ZIPPER EVENTS
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A class of ion distributions has recently been identified by Fennell et al (1980). The distributions are composed of two components, a low-energy component with peak fluxes directed along the field line, and a high energy component with peak fluxes in the perpendicular direction. The transition between the two components occurs over a very narrow range of energies, but can occur anywhere between ~several hundred eV and 20 keV. Because of the appearance of this distribution on an energy vs. time spectrogram, the ion events have been called zippers. The purpose of this report is to examine the mass composition of the zipper events. We find that the low energy and parallel component is composed primarily of 0^+, with to a lesser degree H^+ and a trace of He^+. The high energy and perpendicular component is predominantly H^+, with the relative abundances of 0^+ and He^+ down from those of the low energy component by a factor of ~10. These results suggest that whereas the low energy component is probably ionospheric in origin, the source of the high energy component is most probably the plasmasheet.
J. Geophys. Res., Blue, Paper A10143

5780 Wave propagation
THE EFFECT OF MHD WAVES ON THE THRESHOLD WAVE FIELD FOR INITIATING VLF NON-LINEAR GROWTH AND EMISSIONS
Richard L. Dowden (Department of Physics, University of Otago, Dunedin, New Zealand)
VLF non-linear wave growth can only be initiated by signals above some threshold amplitude. Current theories do not predict this for a uniform or smoothly varying geomagnetic field. It is shown here that if near-resonant electrons see fluctuations in the total field of sufficient frequency and amplitude, cyclotron wave trapping and thus non-linear growth cannot occur. MHD waves in the VLF interaction region have sufficient amplitude (>2γ) on rare occasions to raise the threshold above VLF growth saturation level while MHD background levels of around .05γ would produce a base level threshold only a little below an estimate made from a VLF event and described here.
J. Geophys. Res., Blue, Paper 1A0005

5790 Instruments and techniques
WHISTLER-MODE SIGNALS: SPECTROGRAPHIC GROUP DELAYS
H.R.Thomson [Physics Department, University of Otago, Dunedin, New Zealand]
VLF Doppler frequency shifts and group delays for individual whistler ducts can now be separated and displayed in a multi-duct environment. These measurements of the simultaneous motions of the individual ducts show that there is quite commonly a significant and readily measurable spatial variation in the azimuthal electric field in the magnetosphere. The experimental technique, which involves an improvement of the previously reported computer cross-correlation method, also allows the use of MSK coded VLF transmissions as well as allowing the whistler-mode signals to be received from any direction without a null in the direction of the subionospheric signal as before. (Whistler-mode, electric field, duct drift).
J. Geophys. Res., Blue, Paper 1A0075

Physical Properties of Rocks

6110 Elasticity, fracture, and flow
TIME DEPENDENT FRICTION OF GRANITE: IMPLICATIONS FOR PRECURSORY SLIP ON FAULTS
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Frictional forces were measured during sliding between saw-cut cylinders of Barre granite deformed in a servo-controlled triaxial loading machine. Two different effects occur, depending on the type of loading. When steady shortening of a stably sliding sample is halted suddenly, slip continues at a diminishing rate, which depends on the logarithm of the initial sliding velocity. Thus, the frictional strength of the surface is decreasing with time. When shortening at a constant rate resumes after the holding period, however, the frictional resistance temporarily rises to a peak proportional to the logarithm of time of no driving, showing a well-known increase in friction with time. The subsequent decrease in resistance from this peak is continuous. The observed frictional resistance of a surface thus results from the interaction of several processes and is not a constant, in general, but depends on the immediate and preceding deformation. When shortening is resumed after a period of holding, slip rate across the friction surface temporarily accelerates above the driving rate. The slip rate can then either decrease to the driving rate and remain stable or accelerate further and lead to stick-slip motion, at stress levels below the peak value. There is no apparent difference in the frictional resistance, until the unloading rate of the loading machine is exceeded, between slip episodes which settle stably to the constant driving rate and those which become unstable and result in stick slip. The stick-slip failure criterion is not a peak stress but rather loss of strength more rapidly than the unloading rate of the loading machine. The evidence that accelerating motion before stick-slip is due to the time-variable strength of rock suggests that accelerating slip will occur before earthquakes. Unfortunately for easy observation, experiments indicate that slip need not be uniform over a fault surface. Also to be established is whether slip will be sufficiently large in the earth to be detectable. Nevertheless, a plausible mechanism for generating observable phenomena prior to earthquakes is suggested by the laboratory observations.
J. Geophys. Res., Red, Paper 1B0241

6120 Equations of state
SHOCK COMPRESSION MEASUREMENTS OF SINGLE-CRYSTAL FORSTERITE IN THE PRESSURE RANGE 15-93 GPa
Y. Syono (The Research Institute for Iron, Steel and Other Metals, Tohoku University, Sendai 980, Japan), T. Goto, J. Sato and H. Takei
Shock compression experiments have been performed on pure synthetic single crystal forsterite (Mg_2SiO_4) in the pressure range 15-93 GPa, using a newly installed two-stage light gas gun. The values of HEL vary with the shock propagation directions with respect to the crystallographic orientations, reflecting a notable elastic anisotropy in the olivine crystal. The largest value of HEL up to 12 GPa is observed in the shock direction parallel to [010]. In the hydrostatic regime, shock data in the shock velocity (U_s)-particle velocity (u_p) plane are divided into two parts by a transient plateau around U_s = 8.4 km/s indicating a phase transition. For the shock data of the low pressure olivine phase below about 50 GPa, a linear fit with the equation $U_s = C_0 + s\,u_p$ has yielded parameters of C_0 = 6.26 km/s and s = 1.12. The value of C_0 is close to the bulk sound velocity of forsterite. Murnaghan-Birch fit of shock data for the low pressure olivine phase incorporated with the static compression data by Olinger [1977] has resulted in K_0 = 13 GPa and K_0' = 3.4, which are in reasonable agreement with the ultrasonic data. Close correspondence of the present shock data to the observation of shock residual effects in olivine is noteworthy. The appearance of melt zone or diaplectic glass observed above about 50GPa seems to correspond to the onset of the phase transition inferred in the present measurements. (Shock compression, forsterite, high pressure, phase transition).
J. Geophys. Res., Red, Paper 1B0570

Planetology

6570 Surface (first km) of moon (mechanical properties, topography, albedo, etc.)
HIGH RESOLUTION ALBEDO MEASUREMENTS OF IO FROM VOYAGER 1
R. Todd Clancy (California Institute of Technology, Pasadena, CA 91125) and G. Edward Danielson
The photometric properties of the surface of Io were investigated at high spatial resolution by a choice of 220 sample regions from the four-color, 8 km/lp resolution photomosaic of Io taken by Voyager 1. The mosaic longitudinal coverage extends from ~200°W to 350°W (phase angle ~10.5°). The regions were categorized on the basis of their visual color in the color print. Categories include: white, yellow, orange, red, brown (polar), and black regions.
The photometrically corrected data were plotted as a function of intensity versus photometric angles for each of the color regions in all four filters (orange, blue, violet, UV) using a Minnaert function. The plots of these color regions show large scatter about the least squares fitted lines. The large scatter, particularly for the darker regions, indicates a continuous distribution of albedos on Io and gives evidence of compositional mixing. In all cases, limb darkening coefficients with useful error bounds (e.g., error <0.2) are found only for the white (k = 0.6 ± 0.1) and brown (k = 0.8 ± 0.1) regions. The larger coefficient found for the brown regions is biased upwards due to polar darkening. Computed values of the limb darkening do not change significantly among filters.
Color ratio plots of the reflectances for each of the regions were constructed (UV blue and violet/blue versus orange/blue). The distributions of ratios of the various color regions are compared to laboratory measurements of solid SO_2 [Nash et al., 1980] and various allotropes of sulfur (from J. Veverka and J. Gradie, Cornell). These comparisons indicate SO_2 is the major component (photometrically) of the "white" regions. Red and white sulfur are seen as variable components of these regions. Color ratios of "brown" regions suggest a mixture of white and red sulfur. A significant portion of the "brown" regions have color ratios near those of pure white sulfur. A component of SO_2 is found for all "brown" regions and appears to be latitude dependent. Red regions appear well described by a mixture of red and orange sulfur.
J. Geophys. Res., Red, Paper 1B0118

6580 Tektites
DIMINISHED TEKTITE ABLATION IN THE WAKE OF A SWARM
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Among specimens of any tektite strewn field, surface ablation markings indicate that a large variation occurred in the aerodynamic heating of these specimens. It seems incompatible that some tektites (exhibiting ring wave melt flow) must have entered the atmosphere at greater than escape velocity, whereas others (exhibiting sharp surface features) seem to have entered at much lower velocities. A reconciliation is proposed in the form of a wake shielding model, from which it is concluded that tektites trailing in the wake of a swarm experienced diminished heating. Calculations indicate that wake tektites may have entered at greater than escape velocity while barely reaching melt temperature at the surface. (Tektites, ablation, aerodynamic heating, wake, atmospheric entry, swarm motion).
J. Geophys. Res., Red, Paper 1B0206

Seismology

6920 Explosion seismology
CONSTRAINTS ON CRUSTAL STRUCTURE IN EASTERN ICELAND BASED ON EXTREMAL INVERSIONS OF SEISMIC REFRACTION DATA
K. MacKenzie (Scripps Institution of Oceanography, A-015, University of California at San Diego, La Jolla, CA 92093) J. McClain and J. Orcutt
In the summer of 1978 the Iceland Research Drilling Project undertook the drilling of a deep crustal hole near Reydarfjördur in eastern Iceland. As a part of this project, the Scripps Institution of Oceanography and the University of Washington undertook a small scale seismic refraction experiment near the drillsite in an attempt to compare surface geophysical measurements with observations of samples from, and logging in the hole. Using recent advances in the methods of extremal inversion of seismic data, we have determined an approximate one-dimensional velocity structure for the drillsite. This structure indicates that the 1.9 km hole failed to penetrate the layer 2-layer 3 transition which was at some 3.0-4.5km beneath the drillsite. The transition appears to be rather abrupt, unlike that beneath the ocean, with velocity increasing from 5.2-6.5km/sec in the upper crust to about 6.7km/sec in layer 3. We observe a steep eastward dip and a shallow westward dip in the lower crust away from the nearby Thingmuli and Reydarfjördur volcanic centers, respectively, in agreement with previous work associating shallow depths to layer 3 with Tertiary volcanic centers as a result of increasing metamorphic grade and increased dyke swarm intensity. (Seismic refraction, Iceland, inversion, crustal structure).
J. Geophys. Res., Red, Paper 1B0109

6950 Seismic sources (mechanisms, magnitude, frequency spectrum, space and time distri.)
PRECURSORS TO THE KALAPANA M=7.2 EARTHQUAKE
Max Wyss (CIRES, University of Colorado, Boulder, CO 80309) F.W. Klein and A.C. Johnson
The Kalapana, Hawaii earthquake of November 1975 had a rupture length of 40 to 50 km and was located on the south flank of the active volcano Kilauea. The source mechanism was dip-slip normal faulting on a plane dipping 20° to the SE, with the greatest principal stress oriented in that direction and accumulated by volcanic intrusions into Kilauea's rifts. The source area of the 1975 earthquake was subject to intensive geological and geophysical research for many years before this earthquake because of its proximity to the volcano. We studied the distribution of epicenters for small earthquakes from 1962 to 1975. Seven seismographs located within 3 km of the aftershock area had been in operation for 4 to 10 years before the mainshock and geodetic triangulations and trilaterations in the source area had been carried out repeatedly since 1914. We found that precursory changes occurred throughout most of the rupture area, but in two distinctly different patterns. In the larger outer anomalous area the seismicity rate was decreased by 50% during the 3.8 years before the mainshock; in addition several geodetic lines indicated anomalous strain release during this time. Within two inner areas the seismicity remained high, then increased shortly before the mainshock. In one of the inner areas a P-wave travel time delay of 0.2 sec could be detected, which began about 3.5 years before the mainshock. Within the other inner anomalous area geodetic strain was accumulating until the first half of 1975 when $3.5 \cdot 10^{-4}$ strain (35 bars), was released aseismically. By contrast, the outer anomalous volume was experiencing strain softening from 1970/71 on. We interpret these observations as indicating that strain softening by fault creep in the outer anomalous area transferred stress into two major asperities (locked portions of the fault). A velocity decrease and foreshocks were observed in one asperity and high stress accumulation in the other, implying that dilatancy of the crust probably occurred. Our model is qualitatively supported by the independent evidence of strong motion records which show that the Kalapana earthquake was a complex multiple rupture. We conclude that the Kalapana earthquake was preceded by a preparatory process which lasted 3.8±0.3 years and which had dimensions of 45 x 10 km covering approximately the aftershock area. (earthquake prediction, precursory anomalies)
J. Geophys. Res., Red, Paper 8OB1427

6950 Seismic sources
PRECURSORY CHANGE OF SPECTRAL CHARACTERISTICS BEFORE THE 1978 MIYAGIKEN-OKI EARTHQUAKE
K. Saito (Geophysical Institute, Faculty of Science, Tohoku University, Sendai 980, Japan) and T. Hasuda
A moderate earthquake (Jun.8, 1977, M=5.8) occurred about one year before the 1978 Miyagiken-oki earthquake (Jun.12, M=7.4) off the coast of Miyagi prefecture, northeastern part of Japan, and an obvious change of seismic activity of small earthquakes (M=1.5 - 4.0) was seen before and after this event in the focal region of the main shock and its vicinity. The change of seismic activity suggests the change of stress state in the region, and it is expected that the spectral characteristics also undergoes a temporal variation. In this paper, the spectral characteristics of about 130 small earthquakes previous to the main shock are compared between the two periods before and after the moderate earthquake on Jun.8, 1977. The result shows a distinctive difference of the relation between the seismic moment and stress drop for the two periods. In the former period, source dimension is constant and small on the average, while in the latter period, it is not constant but increases with increasing seismic moment. This implies that the stress field in the focal region has been approaching to the condition where a slight rupture has been readily followed by a greater rupture, and at last the energy release as the main shock has taken place on the whole area of a fault. (Seismic moment, stress drop, source dimension).
Sci. Rep. Tohoku Univ., Ser. 5 (Tohoku Geophys. Journ.) Vol. 27, No. 3-4, 1980

6950 Seismic sources
GROUND MOTION IN THE NEAR-FIELD OF A FLUID-DRIVEN CRACK AND ITS INTERPRETATION IN THE STUDY OF SHALLOW VOLCANIC TREMOR
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We present a study of the motion of the ground in the near-field of a fluid-driven tensile crack embedded in a layered half-space. The source that we consider is the jerky opening of a channel connecting two fluid-filled cracks, and the cause of this opening is the excess pressure of fluid in one of the cracks. We make a complete representation of the three components of ground motion in the space, time, and frequency domains and analyze the effects of fluid compressibility, source depth and medium structure on the ground response. The calculations show the presence of a dominant frequency of motion which depends not only on the source geometry and bulk modulus of the fluid, but also on medium characteristics, receiver position, and the component of motion being considered. Using this source model, we view an episode of volcanic tremor as a continuous sequence produced by numerous jerky openings of channels occurring randomly in time along a chain of cracks. Our results are applied to the October 5-6, 1963 east rift eruption of Kilauea volcano, Hawaii, and found to be compatible with available seismic data, suggesting that magma is transported through an ensemble of cracks with the area of 1 by 1 km, each pair of cracks constituting an individual dike segment which opens in discrete increments at a rate of 1 per second. We obtain the following parameters for each dike-segment opening: increase in cavity volume, 40 m³; stress drop, 0.004 bar; seismic moment, 10^{13} dyne cm and force applied by the fluid to open the dike, $10^{1?}$ dyne. The total moment integrated over the entire duration of tremor for the eruption is $0.5 \cdot 10^{2?}$ dyne cm, roughly equivalent to a single magnitude M5 earthquake. The seismic source parameters and other field observations offer constraints on the process of mass transport and are compatible with the excess pressure and viscosity of magma of about 40 bar and $10^?$ poise, respectively. (Volcanic tremor, magma transport).
J. Geophys. Res., Red, Paper 1B0365

6970 Structure of the crust and upper mantle
EVIDENCE FOR THE SUBDUCTING LITHOSPHERE UNDER SOUTHERN VANCOUVER ISLAND AND WESTERN OREGON FROM TELESEISMIC P WAVE CONVERSIONS
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Long-period teleseismic P waves recorded at VIC (Victoria, British Columbia) and COR (Corvallis, Oregon) show anomalously large Ps conversions and later arriving P-to-S reverberations not observed from typical continental crustal sections or from previously proposed structures for these stations determined from refraction surveys. The timing and large amplitude of the Ps phase, relative to direct P, suggests a high velocity-contrast interface at 45 to 50 km depth under VIC and COR forming the base of a distinct low velocity zone. This interface is proposed to be the oceanic Moho which is being subducted under North America. Off azimuth Ps recorded at COR is consistent with a 20° eastward dip for the interface. Horizontal particle motion at both sites show evidence for lateral heterogeneity in local crustal structure. The distinct low velocity zone and its negative velocity gradient with depth has important consequences for refraction interpretation in the region since the usual assumption of increasing velocity with depth is violated. Crustal thicknesses derived from such misinterpretation may be overestimated. In principle, this type of structure suggests a solution for the Vancouver Island crustal thickness problem in which the observed positive Bouguer gravity anomaly is inconsistent with the 50 km thick crustal thickness derived from previous refraction work.
J. Geophys. Res., Red, Paper 8OB1683

6970 Structure of the crust and upper mantle
SHEAR-WAVE VELOCITIES AND CRUSTAL STRUCTURE OF THE EASTERN SNAKE RIVER PLAIN, IDAHO
R. Greensfelder (Department of Geophysics, Stanford University, CA) and R. Kovach
The lithospheric velocity structure beneath the eastern Snake River Plain (ESRP) is inferred from data on Rayleigh wave dispersion (periods 6 s to 40 s) and teleseismic shear-wave delays, as well as other data from refraction profiling, heat flow, volcanic history, and geology. The unusual velocity structure indicates a 12-km thick high-velocity layer (depth 8 to 20 km), with P- and S- velocities of 6.54 and 3.87 km/s, respectively; this overlies a 21-km thick lower crust, with P- and S- velocities of 6.82 and 3.81 km/s respectively. P- velocities and layer thicknesses are based on our interpretation of refraction data (Braile et al., 1979) and are similar to the results of Sparlin et al. (1979). Upper-mantle S-velocity is 4.1-4.2 km/s, and a lid appears to be absent or weakly developed. Although the mild shear-velocity inversion in the lower crust might result from viscous effects (possibly due to partial melt), an anomaly in mineral composition is the preferred explanation. This may be a major depletion of quartz, as a result of its fusion into the voluminous rhyolitic magmas which erupted onto the ESRP between 10 and 6 m.y. ago. The overlying high-velocity layer is thought to comprise acidic and basic intrusions of late Cenozoic age, and Archean granitoid rocks whose velocity and density may have been increased by thermal metamorphism related to plutonism. (S-wave velocities, crustal structure).
J. Geophys. Res., Red, Paper 1B0298

6970 Structure of the crust and upper mantle
A CRUSTAL SEISMIC REFRACTION STUDY IN WEST-CENTRAL ARIZONA
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A reversed seismic refraction profile was recorded in the southern Basin and Range province between Parker and Globe, Arizona. Interpretation of both refracted and reflected phases indicates a two-layered crust 23-25 km thick, and a low Pn velocity (7.67 km/sec). Pn/Pn amplitude analysis on individual traces and synthetic seismogram modeling indicate that a positive velocity [illegible] upper mantle. The low Pn velocity is indicative of partial melting in the upper mantle and implies that the crust is identical with the lithosphere. The heat flow data suggest that the lithosphere was about 40 km thick approximately 5 m.y. ago. On the basis of this, and a negative free air gravity anomaly, we propose that the lithosphere has been thinned from about 40 km to 24 km over the past 5 m.y. and will probably thin and uplift further in the southern Basin and Range in Arizona.
J. Geophys. Res., Red, Paper 1B0373

6970 Structure of the crust and upper mantle
A COMPARISON OF THE UPPER MANTLE STRUCTURE BENEATH NORTH AMERICA AND EUROPE
L. J. Burdick (Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York 10964)
The techniques of modeling upper mantle structure by matching long period waveforms with synthetic seismograms have been applied to observations from the tectonically stable part of North America and from Europe. The consistent differences which can be resolved by the long period data between Europe and North America can be interpreted in terms of variations in the crust, lid and low velocity zone. At epicentral ranges less than 15°, the effects of shallow lateral variations are strong and body wave propagation is regionally dependent. Between ranges of 15° and 20°, regional effects are still observed, but they can be explained in terms of variations above 250 km. Beyond 20°, wave propagation appears to be stable and independent of region. Most of the observed long period P waves from 20° to 30° are consistent with a single model. This indicates that the relative depths and sizes of the major discontinuities do not vary substantially. A comparison of the upper mantle models of this study with those of other studies indicates that the shape of the P velocity profile is fairly uniform through the transition region (300-700 km) though there may be differences in the absolute depth to the discontinuities. These differences could, however, be the result of systematic errors in travel time data. (Synthetic seismograms, mantle structure, lateral variations.)
J. Geophys. Res., Red, Paper 1B0213

Tectonophysics

8110 Convection currents
STEADY PROPAGATION OF DELAMINATION EVENTS
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Delamination of the lithospheric thermal boundary from overlying continental crust propagates laterally from the line of initiation, accelerating as the sinking slab of detached lithosphere grows longer. This propagation has been numerically modeled with steady-state equations in a moving reference frame by matching an interior finite-element solution to flexible boundary conditions which represent the mechanical and thermal response of the surroundings. The form of the solution depends on the shear coupling of intruding asthenosphere to the top of the sinking slab across a thin layer of crustal material. Without coupling, the tip of the intrusion cools and stiffens to form a wedge dividing the crust (cold mode). With coupling, the intrusion is forced to convect and remains ductile (hot mode). The cold mode can propagate at all velocities; the hot mode has a lower limiting velocity of 1-2 cm/year but offers less resistance at higher speeds. Resistance to delamination includes a constant term from the buoyant crustal downwarp, plus a velocity-proportional term representing viscous deformation. However, the proportionality constant of the latter term is only weakly dependent on crust and lithosphere viscosities. Matching this resistance to loading lines of 100-800 km slabs sinking in a mantle of 10^{21}P, velocities of 0.3 to 8.0 cm/year are obtained. Changes in viscosity affect this rate, but cold-mode delamination is unstoppable except at continental margins or by failure in the sinking slab. The surface expression of delamination is a leading "outer rise" followed by a submarine trough with a large negative free-air anomaly, which finally evolves into a 1-km plateau. If crustal viscosity and velocity are both low, however, there is a nontonic crustal uplift with no trough. Thus the present lack of linear supracontinental oceans does not preclude delamination at up to 4 cm/yr driven by slabs up to 400 km in length.
J. Geophys. Res., Red, Paper 1B0028

8110 Convection currents
LABORATORY CONVECTION EXPERIMENTS:EFFECT OF LATERAL COOLING AND GENERATION OF INSTABILITIES IN THE HORIZONTAL BOUNDARY LAYERS.
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Convection experiments are carried out in a tank with two isothermal heat sinks:the top plate and one of the sidewalls.This situation is similar to that of the Earth's subcontinental mantle in the presence of a neighbouring subducting oceanic lithosphere.Differential interferometry and strioscopy are used to observe the thermal structure of the convecting fluid.The lateral cooling induces a large roll with axis parallel to the cold wall.The variation of its width relative to the values of a vertical and a lateral Rayleigh numbers has been determined.An application to the Earth's upper mantle would predict rolls five times wider than high.For large enough Rayleigh numbers,boundary layer instabilities are observed within the large roll.The interferometric method is very useful for visualizing other time-dependent processes such as the growth of the induced large rolls.This growth is rapid enough to allow us to propose the existence of such large rolls in the Earth and argue that their action could have led to continental breakup. (Convection,subcontinental,experiments,subduction)
J. Geophys. Res., Red, Paper 1B0369

8110 Convection currents
MANTLE CONVECTION WITH SPHERICAL EFFECTS
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Results of a similarity theory for spherical mantle convection are presented. The single-mode mean field equations are analyzed for convection which is so vigorous that temperature disturbances become localized in thin thermal boundary layers. Our purpose is to study effects of spherical geometry, density interfaces, heat source distribution and cell size. Steady state solutions are found for isoviscous spherical shells in which the field of motion is spatially periodic in a single spherical harmonic degree ℓ. Calculations are carried out over the range 2 ≤ ℓ ≤ 40, and for various fractions of internal versus base heating. Three configurations are examined: (i) convection in a single layer of cells extending through the whole mantle; (ii) convection in two layers, separated by a density interface at 670 km depth; and (iii) convection in a single layer terminating at 670 km. Results of these calculations are used to give estimates of surface horizontal velocities in terms of the heat loss, viscosity stratification, amount of internal heating, and depth of circulation. The surface velocity is most strongly affected by the thickness of the convecting shell. Deep mantle convection can achieve surface velocities which agree with observed plate speeds, while convection restricted to the upper mantle does not, at least on the scale of the major plates. The temperature distribution is strongly affected by the spherical geometry and by the presence of density interfaces. The principal difference between convection in one and two layers is that the latter produces a "hot" lower mantle, while the former produces a "warm" one.
J. Geophys. Res., Red, Paper 1B0159

8110 Convection Currents
A SIMPLE GLOBAL MODEL OF PLATE DYNAMICS AND MANTLE CONVECTION
B.H. Hager (Seismological Laboratory, California Institute of Technology, Pasadena, Ca 91125) and R. J. O'Connell (Department of Geological Sciences, Harvard University, Cambridge, Mass. 02138)
Cooling and thickening of lithospheric plates with age and subduction result in large-scale horizontal density contrasts tending to drive plate motions and mantle flow. We quantify the driving forces associated with these density contrasts to determine if they can drive the observed plate motions. First 2-D models are computed to evaluate the effects of assumed rheologies and boundary conditions. We are unable to obtain plate-like behavior in viscous models with traction-free boundary conditions. The piecewise uniform velocities distinctive of plate motion can be imposed as boundary conditions and the dynamic consistency of the models evaluated by determining if the net force on each plate vanishes. If the lithosphere has a Newtonian viscous rheology, the net force on any plate is a strong function of the effective grid spacing used, leading to ambiguities in interpretation. Incorporating a rigid-plastic lithosphere, which fails at a critical yield stress, into the otherwise viscous model removes these ambiguities. The model is extended to the actual 3-D (spherical) plate geometry. The observed velocities of rigid-plastic plates are matched to the solution of the viscous Stokes equation at the lithosphere-asthenosphere boundary. Body forces from the seismically observed slabs, from the thickening of the lithosphere obtained from the actual lithospheric ages, and from the differences in structure between continents and oceans are included. Interior density contrasts such as those resulting from upwellings from a hot bottom boundary layer are assumed to occur on a scale small compared to plate dimensions and are not included. The driving forces from the density contrasts within the plates are calculated and compared to resisting forces resulting from viscous drag computed from the 3-D global return flow and resistance to deformation at converging boundaries; the rms residual torque is ~ 30% of the driving torque. The density contrasts within the plates themselves can reasonably account for plate motions. Body forces from convection in the interior may provide only a small net force on the plates. At converging boundaries the lithosphere has a yield stress of ~ 100 bars; drag at the base of the plates is ~ 5 bars and resists plate motion. The net driving forces from subducting slabs and collisional resistance are localized and approximately balance. Driving forces from lithospheric thickening are distributed over the areas of the plates, as is viscous drag. The approximate balance of these two forces predicts plate velocities uncorrelated with plate area, as observed. The model represents a specific case of boundary layer convection; the dynamical results are consistent with either upper mantle or mantle wide convection. (Mantle convection, plate tectonics, plate driving mechanism).
J. Geophys. Res., Red, Paper 1B0[illegible]

8150 Plate tectonics
DOUBLE SEISMIC ZONE BENEATH THE MARIANAS ISLAND ARC
Ilene R. Samowitz and Donald W. Forsyth (Department of Geological Sciences, Brown University, Providence, RI 02912)
A double zone of seismicity has been found beneath the northern Marianas in the depth range 80 to 120 km. The Benioff zone undergoes a pronounced bend, with radius of curvature about 200 km, before straightening and descending nearly vertically to a depth of more than 600 km. Thus, this is an ideal area in which to search for evidence of stresses associated with unbending of the subducted oceanic plate. We relocated all teleseismic events from 1963 through 1975 using a regional, composite master-event technique, which significantly decreased the scatter of the hypocenters. The three events of the lower seismic zone are separated from the upper zone by about 30 to 35 km. The true thickness of the upper seismic zone is probably 20 km or less. The limited focal mechanism data indicates there is downdip tension in the lower zone and downdip compression in the upper zone. The seismicity patterns could be generated either by thermal stresses or by unbending a plate which was originally deformed anelastically. We show that an elastic-perfectly plastic model of the rheology of the plate can account for the separation of the two seismic zones, the focal mechanisms, and the greater activity of the upper seismic zone.
J. Geophys. Res., Red, Paper 1B0372

8150 Plate tectonics
VISCOELASTIC MEMBRANE TECTONICS
S.R. Dickman (Dept. of Geological Sciences, SUNY, Binghamton, N.Y. 13901) and David P. Williams
The theory of membrane tectonics proposed by Turcotte and Oxburgh [1973] to explain intraplate tensional features and earthquakes, and developed by Turcotte [1974] for an elastic lithospheric membrane, is extended to the case of a viscoelastic lithosphere. Such an extension may be expected to seriously modify the theory since, for all lithospheric viscosities except the very highest, the time scale for viscous relaxation is comparable to the time scale for changes in plate curvature. It is found that for most viscosities considered, the membrane stresses generated by changes in plate curvature do not exceed ~10^2 bars. We conclude that either the effective viscosity of the lithosphere is much higher than indicated by most studies, or membrane tectonic stresses play a secondary role in the generation of intraplate features and earthquakes. (Intraplate extension, intraplate earthquakes, lithospheric viscosity).
Geophys. Res. Lett., Paper 1L0009

8170 Structure of the lithosphere.
BASEMENT DRILLING IN THE WESTERN ATLANTIC OCEAN: II. A SYNTHESIS OF CONSTRUCTION PROCESSES AT THE CRETACEOUS RIDGE AXIS.
M. F. J. Flower (Dept. of Geol. Sci., Univ. of Illinois, Chicago, IL. 60680) P. T. Robinson
Geochemical and geophysical studies of basaltic cores obtained from DSDP Sites 417 and 418 (W. Atlantic) show that (Cretaceous) eruptive crust was generated at a stable slow-spreading axis similar to the present Mid-Atlantic Ridge. Interpretation of whole-rock and glass chemical variation in sampled lavas suggest that magma fractionation occurred in temporally and spatially transient storage reservoirs at various depths between the zone of magma segregation and the ridge crest. It is suggested that melt generation, fractionation and eruption comprise single episodes of activity involving rapid upward propagation of fractures. Eruptive episodes are recorded by stratigraphic sequences of contiguous, mostly co-genetic, lavas, separated by breccias, sediment, and/or extreme alteration zones suggestive of lengthy quiescent intervals. Three such episodes are recognized at site 417 (365 meters of basement), whereas seven are recorded in 418A (in 540 meters). Patterns of downhole changes in magnetic inclinations and polarities indicate that iterative burial of successive lava episodes occurs concomitantly with crustal spreading from the axis. From these observations it is predicted that eruptive oceanic crust is imbricated and will show increasing complexity of lithologic chemical and magnetic character with depth. Studies of crack distribution and laboratory measurements of core physical properties indicate preferential zones of water circulation which decrease with depth. Permeability of the lava pile is largely controlled by the eruptive structure. (lithosphere, construction, magma storage ocean crust structure).
J. Geophys. Res., Red, Paper 1B0262

8170 Structure of the lithosphere
OCCURRENCE AND ORIENTATION OF SHATTER CONES IN PRETORIA [illegible] QUARTZITES IN THE COLLAR OF THE VREDEFORT "DOME": IMPACT ORIGIN PRECLUDED
Carol [illegible] (Geologisches Institut, ETH, Zurich [illegible], Switzerland)
Shatter cones have been found cutting completely annealed fault breccia associated with the [illegible] of previously overturned [illegible] Group quartzites and the Vredefort structure. The evidence indicates that the shatter cones formed later than the overturning. Hence they cannot be considered to have been formed by an impact generated shock wave which penetrated the strata just before overturning. (Shatter cones, Vredefort, meteorite impacts, [illegible]).
J. Geophys. Res., Red, Paper 1B0171

8170 Structure of the lithosphere
CRUSTAL GENESIS IN ICELAND: GEOPHYSICAL CONSTRAINTS ON CRUSTAL THICKENING WITH AGE
John F. Hermance (Department of Geological Sciences, Brown University, Providence, RI 02912)
Geophysical experiments in Iceland and adjacent areas suggest that crustal thickening due to underplating provides a significant contribution to the tectonic development of the Iceland Plateau and perhaps of the Iceland-Faeroe Ridge, as well. The interpretation of recent magnetotelluric and seismic refraction experiments suggests a model in which mantle-derived melt accumulates in a thin layer (T<4 km) at the base of the crust beneath the neovolcanic zone. We suggest that, with time, this melt cools, solidifies, and accretes to the base of the crust leading to crustal thickening. Seismic experiments indicate an increase in thickness of the Icelandic crust from 8-10 km directly beneath the neovolcanic zone to an average value of 20 km for the generally older (~10 my) Iceland plateau. The much older Iceland-Faeroe Ridge has a crustal thickness of 30 km. Segregation of material from a significant volume of the mantle and the continued development of the crust, primarily due to underplating, may persist well beyond the boundaries of surface manifestations of volcanic activity, and crustal genesis may continue beneath regions as old as 10 my at the surface. These results are compatible with a simple model of isostatic uplift.
Geophys. Res. Lett., Paper 1L0100

8199 General or miscellaneous
DEEP ELECTRICAL STRUCTURE OF THE COLORADO PLATEAU AS DETERMINED FROM MAGNETOTELLURIC MEASUREMENTS
J. Pedersen (Union Oil Company, P. O. Box 76, Brea, CA 92621) J. F. Hermance
Magnetotelluric measurements on the Colorado Plateau near Farmington, New Mexico characterize the province as consisting of conductive surficial sediments underlain by a more resistive crystalline crust down to about 28 kilometers. Beneath this zone the average resistivity is anomalously low (10-15 ohm-m) down to at least 110 kilometers. Since seismic evidence indicates a crustal thickness of approximately 40 kilometers for the interior of the Plateau, these results suggest that the transition from the resistive upper crust to more conductive mantle material occurs within a lower crustal layer. The values for upper mantle resistivity suggest that the bulk resistivity of the mantle is being influenced by the presence of a small degree of partial melt (~1-2 percent by volume). Temperature estimates associated with the allowable resistivity variations lie within the range of 1100-1200°C at 50 km depth and yield a geothermal gradient in the upper mantle of 3-4°C/km or less.
J. Geophys. Res., Red, Paper 1B0[illegible]

8199 General or miscellaneous
SEISMOTECTONICS OF NORTHEASTERN UNITED STATES AND ADJACENT CANADA
J. Yang (Lamont-Doherty Geological Observatory and Department of Geological Sciences, Columbia University, Palisades, New York 10964) Y. Aggarwal
Data for local earthquakes recorded by a network of stations in northeastern United States and adjacent Canada were analyzed to study the seismicity, the relationship between earthquakes and known faults, the state of stress, and crustal and upper mantle velocity structure. In addition, portable seismographs were deployed in the field to study aftershocks. As a result, accurate locations for about 3?? local earthquakes (2 ≤ m_b ≤ 5) and 22 focal mechanism solutions were determined. A comparison of the spatial distribution of these events (1970-1979) with historical earthquakes (1534-1959) reveals that seismic activity in the northeast is relatively stationary in space: those areas that have had little or no seismicity historically are relatively aseismic today, whereas the historically active areas are also active today. The instrumental locations, historical seismicity, and focal mechanism solutions show an internal consistency that help us distinguish two distinct seismogenic provinces.
The Adirondack - Western Quebec Province: A northwesterly trending zone of seismic activity, about 200 km wide and at least 500 km long, extending from the NE Adirondacks into western Quebec, Canada. Thrust faulting on planes striking NNW to NW appears to predominate and the inferred axis of maximum horizontal compression is largely uniform and trends WSW, nearly parallel to the calculated absolute plate motion of North America. Little or no seismicity is found where anorthosite outcrops at the surface. Correlations between gravity anomalies and earthquake locations suggest that seismic activity in this zone is localized to regions of steep NE or SW gradient in Bouguer anomalies. This zone does not appear to extend southeastward to Boston as proposed by some workers. The Appalachian Province: A northeasterly trending zone of seismic activity extending from northern Virginia to New Brunswick, Canada. High-angle reverse or thrust faulting on N to NE trending planes appears to predominate. The western margin of this province, however, appears to be relatively aseismic. We attribute this relative lack of activity to one or more of the following: 1) the presence of igneous activity postdating rifting of Africa from North America, 2) the occurrence of intense metamorphism during the Acadian orogeny which may have annealed pre-existing faults, and 3) the predominance of ductile as opposed to brittle deformation in the geologic past. The inferred axis of maximum horizontal compression along the eastern margin of the Appalachians is rather uniform and trends W-WNW, almost perpendicular to the magnetic lineations offshore. We suggest that this W-WNW compression reflects the gravitational force arising from horizontal density variations in the oceanic lithosphere as it cools and moves away from spreading centers. (Epicenters, magnitude, focal mechanism solution, maximum principal stress).
J. Geophys. Res., Red, Paper 1B0080

8199 General or miscellaneous
PREDICTION OF VERTICAL DISPLACEMENTS IN A SUBSIDING ELASTIC LAYER
William Z. Savage (U.S. Geological Survey, Box 25406, M.S. 993, Denver, Colorado 80226)
Subsidence over an underground cavity is modeled by assuming the subsiding region [illegible] an infinitely long elastic layer that r[illegible] rigid base and deforms under its own [illegible] an opening under its lower surface. [illegible] analytic solution based on [illegible] form methods is found for vertical [illegible] of the ground surface and the [illegible] ing when the layer thickness [illegible] than the width of the open[illegible] fers from previous analy[illegible] both the ground surfac[illegible] traction-free. The [illegible] dence trough is [illegible] ratio of the la[illegible] opening; as the [illegible] the subsidence [illegible] ridge form[illegible] subsurfa[illegible]
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